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## ARISTARCH A. BELOPOLSKY

By B. P. GERASIMOVICH

In the death of Professor A. A. Belopolsky of the Pulkovo Observatory the science of astrospectroscopy has lost one of its pioneers and foremost authorities, one of those few scientists who by their works and discoveries have prepared the way for the amazing growth of our science in the last two decades.

Aristarch Apollonievič Belopolsky was born in Moscow on July 13, 1854, the son of a well-educated teacher. One of his forefathers had come to Russia from the Serbian town of Belopolje, from which the family name was derived. Belopolsky received a good secondary education and entered Moscow University, from which he graduated in 1877. As a child he was fond of making physical experiments of various kinds and of observing insects, reptiles, etc. To provide the necessary rudimentary equipment he studied handicraft and sharpened his mind by making small inventions. These interests developed his admirable mechanical ability, which became so important in his future scientific work. Professor T. Bredichin, then director of the Moscow Observatory, met the young student and greatly appreciated his mental vigor and technical skill. He invited him to participate in the solar observations at the Observatory and soon gave him a place as an extra assistant. Here at the Observatory Belopolsky experienced all the benefits of personal contact with such a remarkable man as Bredichin. In later years he would recall with great pleasure and appreciation Bredichin's Sunday

parties, which attracted the most refined intellectuals and scientists, who informally discussed science and art. At Moscow, Belopolsky divided his time between solar photography and meridian observations. In 1886 he successfully completed his dissertation on the motions of sun-spots, and in 1888 he was invited by Otto Struve to join the staff of the Poulkovo Observatory. At the beginning of his Poulkovo career he was busy with the reductions of the material obtained with the transit circle, and derived some parallaxes from the fundamental observations of right ascensions.

Bredichin's appointment as director of the Poulkovo Observatory greatly affected Belopolsky's work. He was given charge of all the astrophysical equipment of the Observatory and was sent to Potsdam for spectrographic studies.<sup>1</sup> Bredichin gave him a special commission to order a "Carte du ciel" astrograph and several stellar spectrographs. Upon coming home with the new equipment Belopolsky started his remarkable spectrographic work, which he continued for more than forty years, until his death. At first he worked with a spectrograph of the Potsdam type attached to the 15-inch refractor and to the "Carte du ciel" astrograph. Very soon, however, he received the following characteristic order from Bredichin: "to employ all means without sparing money and time to adapt the spectrograph as quickly as possible to the 30-inch refractor." The lenses of the 30-inch Poulkovo refractor are of the visual kind and this badly hampered Belopolsky's work, until upon adopting a correcting lens he was enabled to obtain stellar spectra of fourth to fifth magnitude, with reasonable exposure times.

At first Belopolsky's results met with rather severe criticism from leading German astronomers who were at that time monopolists in the science of astrophysics. Wilsing objected to his discovery that the law of solar rotation as determined from faculae is the same as that from sun-spots. Vogel attacked his observations of Nova Aurigae, doubting the abundance of details shown on the Poulkovo spectrograms (amply confirmed afterward by Harvard plates). However, neither of his opponents was right.

In 1894 he discovered the periodic changes in the radial velocities

<sup>1</sup> See E. B. Frost's reminiscences on their joint stay at Potsdam in his *An Astronomer's Life*.

of  $\delta$  Cephei which are synchronous with the light-variation, noticing the well-known shift in phase of both curves. The corresponding discovery for  $\eta$  Aquilae followed in 1896, and that for  $\zeta$  Geminorum in 1899 (prior to W. W. Campbell, who was, however, the first to publish his results). In 1895, independently of Keeler and Deslandres, he discovered the law of rotation of Saturn's ring (a remarkable coincidence: both Keeler and Belopolsky started their observations of Saturn in the same month—April, 1895—Keeler publishing his results a few months before Belopolsky). In the meantime he proved  $\alpha^1$  Geminorum to be a spectroscopic binary and investigated the spectra of  $\beta$  Lyrae,  $\lambda$  Tauri, Jupiter, P Cygni, etc. Working on  $\gamma$  Virginis and  $\gamma$  Leonis, he made a very important advance in deriving their parallaxes from the visual orbits and the spectroscopic data. In 1906 he announced a long-period oscillation in the radial velocities of Algol, which he followed for several years; this discovery was afterward confirmed by Curtiss and McLaughlin. A beautiful discovery of two groups of lines in the spectrum of  $\alpha$  Canum Venaticorum, which varied periodically in intensity and radial velocity, was made by Belopolsky in 1913. After that he followed this remarkable star every year, accumulating a large amount of material for a study of its peculiar variations. Another of his intimate friends was Polaris, for which he used to derive the elements every two years, following the changes in  $\gamma$  and discovering the variations in  $\omega$ .

One of the most important of Belopolsky's researches was the experimental proof of the Doppler principle as applied to optical phenomena. It should be recalled that even at the end of the preceding century some very able physicists doubted the applicability of the Doppler principle to optical phenomena. The idea of testing the Doppler principle with a simple rotating mirror, without resorting to cosmic velocities, first occurred to Belopolsky in 1894. In 1898 he got some money from the Elisabeth Thomson Science Fund and made his splendid experiment which put a rigid experimental basis under the whole edifice of stellar spectroscopy.

Belopolsky's work on novae should be mentioned separately. In fact, after the appearance of Nova Aurigae in 1892 he did not miss a single bright nova. In some cases he succeeded in getting the

spectra in their earliest pure absorption stage. He noticed the similarity of the displaced absorption spectrum (after the appearance of emission lines) to those of stars of types A and F which have broad absorption lines. Then using  $\gamma$  Bootis for a comparison spectrum, he was able to measure and follow the violet shift of the absorption lines in novae. One of his remarkable results, confirmed by other observers but not yet explained, refers to a set of very fine undisplaced iron lines which appeared in the spectrum of Nova Aquilae 1918 between June 22 and July 6.

Solar work begun at Moscow was continued by Belopolsky at Poulkovo. Since 1905 he had acted as Russian delegate to the International Solar Union and as president of its Russian branch. In 1912 a substantial grant from the Russian Academy of Sciences enabled him to order from Sir Howard Grubb a large solar spectrograph of the Littrow type having a focal length of 7 m, and giving a dispersion in the third order of  $1 \text{ mm} = 0.76 \text{ \AA}$ . The war delayed the construction of this instrument, which was received at Poulkovo only in 1923. After getting this spectrograph Belopolsky started at once his observations of the solar rotation, as a participant in the international co-operative program (region  $\lambda\lambda 3910\text{--}4007$  and test region  $\lambda\lambda 4196\text{--}4291$ ). These observations showed that the equatorial velocity of the sun was slightly decreasing in 1925–1933; he, however, considered this variation as being of a secular character rather than of a short period.

In this connection it seems important to note the first determination of the temperature of sun-spots, which Belopolsky made by ingeniously applying spectrophotometric methods. His results were published in Russian in 1915.

Professor Belopolsky's service to science was recognized both at home and abroad. In 1903 he was elected a member of the Russian Academy of Sciences, in 1910 he became associate of the Royal Astronomical Society, and he was awarded several Russian and foreign prizes. In 1917 he was appointed director of the Poulkovo Observatory, but he left this office after two years because heavy administrative duties badly affected his research work. A good compromise was found in 1931, when he was appointed honorary director of the Observatory.

Even if one takes into account Belopolsky's many scientific researches and discoveries, it is not upon these alone that his reputation and renown rest. No less important than his individual work was the influence on his generation of his spirit and his aims, through the many students and associates who came to know and appreciate him. His most striking qualities were modesty, moral courage, clear vision, and enormous devotion to science and industry. In the terrible years of the civil war, this old man, cold and hungry, continued his work as usual—an example of true heroism. Last year he lost the sight of one of his eyes. Neglecting all ophthalmological advice, he continued measuring solar spectra. He was highly respected by the present government, which gave him some responsible commissions. His death is a great shock not only to science but to the country where he was born and which he loved so much.

POULKOVO

June 2, 1934

## THE SPECTRUM OF $\alpha$ CANIS MINORIS (PROCYON) (CLASS dF5)

BY SEBASTIAN ALBRECHT

### ABSTRACT

Results are given of a detailed study of seven three-prism spectrograms, taken at the Yerkes Observatory, of the standard velocity star  $\alpha$  Canis Minoris, of class dF5. In order that the results may have a permanent value, all data are included which would be required for a rediscussion of the observed wave-lengths and radial velocities whenever this may prove desirable.

Tables I and II contain the wave-lengths which were employed for the normal and the  $T_i$  reference lines, while Table III gives the radial velocities which, owing to the fundamental way in which the plates were reduced, will qualify as standard velocities. The observations indicate a variation in radial velocity with a period of less than a day. However, a recorded change of  $0.9^\circ\text{C}$  in the temperature within the spectrograph case during the exposure on plate R 1972 casts grave doubts on the reality of the observed short period.

Table IV gives, for 1094 lines, the observed wave-length to  $0.001\text{ \AA}$ ., the probable error, the estimated intensity, the measured width, the number of plates on which measured, and the identification with laboratory and solar lines. One-third of all the identified lines are due to  $Fe$ . For the normal lines the observed wave-lengths have in no case a probable error greater than  $\pm 0.011\text{ \AA}$ , and the average is  $\pm 0.0059\text{ \AA}$ . About 10 per cent of the stellar lines may contain a slight personality displacement due to the close proximity of another line. Such displacements seem to vanish at separations greater than  $0.3\text{ \AA}$ .

The evidence of these measures is negative for systematic displacements of the lines of one element relative to the lines of other elements or of the lines due to neutral atoms relative to those of ionized atoms.  $H\gamma$  shows variations in intensity and width.

In the *Astrophysical Journal*, **72**, 65-97, 1930, results were published of a study of the spectrum of  $\gamma$  Geminorum, class A0, covering the region from  $\lambda 4250$  to  $\lambda 4722$ , which is usually employed in determinations of radial velocity with the dispersion of three prisms. The present paper on the standard velocity star Procyon ( $\alpha 7^h 34^m$ ), class dF5, is the second of a series of studies covering classes A0-Mb.

Procyon is a close visual binary, magnitudes 0.5 and 13.5, with a period of 40.2 years. Seven three-prism spectrograms taken at the Yerkes Observatory were kindly placed at the disposal of the writer by Professors Frost and Struve. All plates were measured with Gaertner spectrocomparator M 1201, No. 104, which had been purchased with funds obtained from the Rumford Committee of the American Academy of Arts and Sciences. Plates B 467 and B 881 had been previously measured with a comparator lent me by the Maria Mitchell Observatory at Nantucket through the kind offices

of Miss Harwood. For the two early measures north sky light was used as the source of illumination for the plates, while for all other measures a daylight lamp provided constant illumination. Each complete measurement of a plate consisted of progressively continuous measures of the positions of the stellar and the reference lines, two settings being made on each line in both direct and reversed positions of the plate on the comparator. With few exceptions the widths of the stellar lines were also measured and their intensities estimated.

TABLE I  
NORMAL WAVE-LENGTHS EMPLOYED FOR STELLAR LINES

4312.866	4415.58	4451.58	4508.287	4571.11
18.645	17.729	54.383	15.337	71.970
24.98	18.34	54.790	20.238	76.34*
25.766	25.44	55.88	28.62	83.838
52.741	33.222	68.493	41.517	88.206
75.934	35.682	76.04	45.96	89.955
83.550	41.72	81.229	47.853	4602.946
94.057	42.346	82.21	54.037	20.52
95.848	43.799	91.41	54.989	29.33
4404.754	44.559	94.572	58.654	
11.08	47.724	4501.269	63.757	

\* .31 is too low for  $Fe^+$ ? Observed:  $\odot$ , .34;  $\alpha$ CMi, .34;  $\gamma$  Gem, .38.

Tables I and II give the wave-lengths for the normal and the reference lines, respectively, which were employed in the reductions and which therefore form the basis for the observed stellar wave-lengths. It should be noted that only laboratory wave-lengths produced under known and controlled conditions have been employed. The results are thus entirely free from the possibility of spurious systematic effects which might be introduced by the use of adjusted stellar wave-lengths for the normal lines. The list of normals includes three blends:  $\lambda$  4324.98,  $\lambda$  4476.04, and  $\lambda$  4481.229. The first two are close blends, the separation between the components being 0.04 Å and 0.06 Å, respectively. For these the uncertainty of the normal wave-length is, therefore, inherently less than 0.01 Å, while the blend of two equal components,  $\lambda$  4481, has a special importance because of the wide range of spectral classes in which it appears. The

close accordance between the adopted normal wave-lengths and their corresponding observed stellar wave-lengths (in Table IV)

TABLE II  
TITANIUM REFERENCE SPECTRUM

$\lambda$ EMPLOYED	OBSERVED			$\lambda$ EMPLOYED	OBSERVED		
	$\lambda$	No. of Plates	Inten- sity		$\lambda$	No. of Plates	Inten- sity
4250.794.....	.782	2	.....	4457.427.....	.435	6	3
60.474.....	.492	2	3	64.458.....	.447	1	1
71.760.....	.768	3	6	65.807.....	.808	1	0
86.006.....	.005	5	1	68.493.....	.489	7	10
87.406.....	.412	4	1	71.239.....	.238	1	— 1
89.072.....	.079	5	2	81.259.....	.266	3	2
90.222.....	.236	6	4	88.319.....	.304	6	2
90.933.....	.944	2	1	89.089.....	.075	1	0
94.103.....	.093	7	4	96.146.....	.152	2	0
95.751.....	.752	2	1	4501.269.....	.277	7	8
98.666.....	.676	6	2	12.734.....	.732	6	1
4300.052.....	.045	7	8	18.024.....	.029	6	2
00.566.....	.560	4	3	22.797.....	.794	6	2
01.089.....	.080	6	3	27.305.....	.300	3	2
01.928.....	.927	3	2	28.....	.630	2	.....
05.910.....	.904	7	6	33.243.....	.243	7	8
07.862.....	.877	7	5	33.966.....	.965	7	7
12.866.....	.867	6	2	34.782.....	.774	7	6
14.....	.906	6	3	35.....	.565	7	3
37.915.....	.908	7	4	35.....	.987	7	4
44.291.....	.287	1	— 1	44.689.....	.700	2	1
67.657.....	.675	4	1	48.....	.785	6	1
86.858.....	.848	1	1	49.624.....	.646	7	14
94.057.....	.036	2	— 1	52.454.....	.446	6	2
95.036.....	.017	7	10	55.485.....	.490	5	1
99.770.....	.772	6	2	63.757.....	.751	7	7
4415.124.....	.131	4	3	71.970.....	.976	7	10
17.718.....	.724	6	2	89.961.....	.956	5	— 1
27.098.....	.100	6	2	4617.270.....	.275	7	2
43.799.....	.791	7	8	23.098.....	.096	4	1
49.143.....	.150	6	1	56.468.....	.468	4	1
50.487.....	.477	3	1	67.585.....	.579	6	1
50.893.....	.898	2	1	81.909.....	.915	5	2
53.308.....	.323	2	1	91.334.....	.348	1	— 1
53.707.....	.698	2	0	98.763.....	.734	1	— 1
55.319.....	.320	5	2				

shows that the stellar wave-lengths are practically free from errors due to uncertainties in the adopted normals. The systematic difference—observed *minus* normal—is 0.0006 Å.

Wave-lengths by Crew and Brown were employed for the *Ti* ref-

erence lines. Interferometer measures by Kiess<sup>1</sup> of 45 of these lines differ from them in the mean by only  $-0.0001$  Å, or, weighted according to the number of plates of Procyon on which they were employed, by  $-0.0004$  Å. The probable error of a reference line for a single observation of weight 1, as determined from two entirely independent complete measures of a plate of Procyon, is  $\pm 0.00044$  mm

TABLE III

Plate	Date (G.M.T.)	Duration of Exposure	Displacement ( $v_g$ )	No. of Lines	Reduction to Sun ( $V_a + V_d$ )	Radial Velocity
		min.	km/sec.		km/sec.	km/sec.
B 467.....	1902, Nov. 27.924	14	-28.94	53	+21.67	-7.27
B 881.....	1917, Mar. 19.656	30	+27.54	53	-25.85	+1.69
R 1963.....	1932, Nov. 5.365	90	-32.58	53	+27.50	-5.08
R 1972.....	14.367	90	-28.64	53	+25.73	-2.91
R 1973.....	14.415	30	-35.93	53	+25.63	-10.30
R 1986.....	24.384	30	-27.51	52	+22.94	-4.57
R 1987.....	24.431	98	-28.39	53	+22.84	-5.55

- B 467—Seed N.H.; strongly exposed; somewhat too strong in the region of longer wave-lengths  
 B 881—Seed 23; much underexposed in the region of shorter wave-lengths  
 R 1963—Eastman Process; violet end underexposed; reference spectrum very faint at red end  
 R 1972—Eastman Process; well exposed, even at  $\lambda 4275$ ; reference spectrum good; recorded temperature change of  $+0.9^\circ$  C in spectrograph box during exposure  
 R 1973—Eastman 40; violet end somewhat underexposed; reference spectrum good; negative displacement relative to R 1972 readily visible under microscope  
 R 1986—Eastman 40; exposure good  
 R 1987—Eastman Process; exposure very good at  $\lambda 4300$ ; overexposed beyond  $\lambda 4500$ ; reference spectrum fair

(which equals  $\pm 0.0045$  Å at  $\lambda 4500$ ). The average value of the probable error for the observed mean of a reference line (Table II) is  $\pm 0.0026$  Å.

Table III gives the observed radial velocities and other plate data. Owing to the fundamental character of the reductions, the radial velocities derived for this standard velocity star, except for the reservations made below, will qualify as standard radial velocities.

<sup>1</sup> Bureau of Standards Journal of Research, July, 1928.

These measures formed the basis for the announcement<sup>2</sup> that Procyon is a triple star, the bright component of the visual pair being a spectroscopic binary with a total range of variation in velocity of about 12 km/sec. and a period of the order of one-fourth of a day. The evidence for this short period of velocity variation rests largely on the observed variation of 7.39 km/sec. in a time interval of only 1<sup>h</sup>08<sup>m</sup> on November 14, 1932. There is no doubt whatever about the relative displacement on the two spectrograms. In fact, when the two plates are superimposed face to face under the microscope, the relative displacement can readily be seen without actually making any measurements. However, Dr. Struve has recently found in the observing records a recorded change of temperature in the temperature control case from +2°3 C at the beginning of the exposure on R 1972 to +3°2 C at the end of the exposure. A change in temperature of this order of magnitude is, of course, entirely unpermissible and casts grave doubts on the radial velocity and on the short period. Dr. Struve believes that because of the uncertainty of plate R 1972 the following plate, R 1973, though not suspected by the observer, should also be regarded with doubt. An inspection of R 1972 shows that the quality of the stellar lines has not been appreciably affected by the recorded temperature change of 0°9 C during the exposure time. The reference lines likewise are good and in line above and below the star spectrum. Moreover, the average measured width of 52 normal lines is 0.39 Å for R 1963, 0.39 Å for R 1972, 0.41 Å for R 1973, and 0.34 Å for R 1987 (much overexposed). This leads the writer to believe that there is a slight possibility that only a recording error in the temperature may be involved. Under the circumstances, judgment on the reality of the short period must be held in abeyance until a new series of spectrograms can be secured and measured.

The observed stellar wave-lengths derived from plates B 467 and B 881 were corrected for the coma of the camera lens, the corrections, which were determined from the observed wave-lengths, varying from -0.022 Å at  $\lambda$  4280 to +0.017 Å at  $\lambda$  4600. The five more

<sup>2</sup> *Publications of the Astronomical Society of America*, 7, 210, 1933, and *Carnegie Institution Year Book*, 32, 287, 1932-1933.

recent plates were found to be free from coma and required no corrections. The recorded large temperature change during the exposure on R 1972 does not seriously affect the wave-lengths derived from the measures of that plate. Table IV contains a summary of the means of the observed wave-lengths, their probable errors, intensities, and widths, the number of plates on which measured, and identifications with laboratory and solar lines. These measures, in view of the fact that they have not been corrected or adjusted to conform to any theory, should continue to have unimpaired usefulness in connection with advancing and changing concepts.

The relatively accurate observed positions of the lines play a controlling rôle in establishing individual identifications, and in deciding upon the relative contributions of components in blends and the reality of deviations from intensities inferred from laboratory and solar data. Identifications were facilitated quite materially—owing to the proximity of class F<sub>5</sub> to the solar type (class G) in the sequence of stellar spectra—by the use of the Mount Wilson revision of Rowland's *Preliminary Table of Solar Spectrum Wave-Lengths*, containing also supplementary data on line intensities in the sun-spot spectrum. The progression from sun-spot to sun indicated in the Mount Wilson tables for individual line intensities continues, with apparently only a few minor exceptions, quite regularly and in the same direction to  $\alpha$  Canis Minoris. Important collateral evidence is found in laboratory data used in conjunction with modern theory. Black-face type is employed in some cases in the last column to assist in indicating greater effectiveness in producing the observed stellar line. In quite a number of instances where close lines were measured separately settings were also made on the estimated center of gravity of the blend. Such measures, indicated in the last column of Table IV as "bl. of prec. lines" or "bl. of foll. lines," often furnish corroborative information in addition to that given by the measures of the separate components, and also have a prospective value in the reduction and discussion of spectrograms taken with lower dispersion.

TABLE IV

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E.* (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4250.10				1	.13 Fe, $\odot$ 8, sp. 8
50.49				1	.47 $\odot$ ? - 1
50.79	22	4	50	2	.79 Fe, $\odot$ 8, sp. 9
54.34		6	39	1	.34 Cr, $\odot$ 8, sp. 12
58.13		4	30	1	.16 Fe <sup>+</sup> , $\odot$ 1N, sp. oN
58.40		1	14	1	.32 Fe, $\odot$ 2, sp. 4; .49 $\odot$ oN, sp. o
59.18		1	26	1	.10 $\odot$ o, sp. o; .15 $\odot$ o, sp. o; .26 Mn <sup>+</sup> , $\odot$ 1 Nd?, sp. 2
59.48		1	22	1	.51 $\odot$ ? - 2N, sp. - 1
59.80		0	14	1	.77 $\odot$ oN, sp. o
60.06		3	20	1	.99 Fe, $\odot$ 2, sp. 3; .13 Fe, $\odot$ 3d?, sp. 3
60.44		4	23	1	.49 Fe, $\odot$ 10, sp. 9
60.67		0	21	1	.62 $\odot$ oN; .72 Fe Pred., $\odot$ 1
61.00		3	47	1	.90 Cr <sup>+</sup> ; .81 Cr <sup>+</sup> Pred. and .84 Nd <sup>+</sup> indetermin.
63.16	27	1	22	2	.13 Ti, .14 Cr, $\odot$ 2, sp. 3; .27 $\odot$ o, sp. - 1
63.66		-1	27	1	.61 $\odot$ , La <sup>+</sup> od?, sp. o
64.10		-1	46	1	.98 $\odot$ 1, sp. 1; .21 Fe, $\odot$ 3, sp. 3
64.54		1	23	1	.47 $\odot$ ? 1, sp. 2
65.30		-1	15	1	.26 Fe, $\odot$ 2, sp. 2
65.98		1	22	1	.92 Mn, $\odot$ 2, sp. 3
66.70		1		1	.70 Zr <sup>+</sup> ; .71 Nd <sup>+</sup> ?
67.01		2		1	.97 Fe, $\odot$ 3, sp. 3
66.92		2	72	1	Bl. of 2 prec. lines and ?
67.87		3	57	1	.75 $\odot$ 1; $\odot$ 83 Fe, $\odot$ 3; .98 $\odot$ o, sp. o; .11 $\odot$ 1N, sp. 1
68.78		2	20	1	.75 Fe, $\odot$ 2, sp. 3
71.156	13	5	38	4	.16 Fe, $\odot$ 6, sp. 6
71.470				1	.38 $\odot$ ? o
71.785	12	7	42	4	.77 Fe, $\odot$ 15, sp. 12
73.378	10	1	26	3	.31 Fe <sup>+</sup> , $\odot$ 3N, sp. 3; .49 Zr <sup>+</sup> , $\odot$ 2N, sp. 2
74.825	11	4	35	5	.80 Cr, $\odot$ 7d?, sp. 12
75.613	12	3	39	3	.56 Cr <sup>+</sup> , $\odot$ o, sp. - 1; .65 La <sup>+</sup> , $\odot$ o; 71 $\odot$ o
76.71		-1	24	1	.69 Fe, $\odot$ 2, sp. 2
78.196	6	1	36	4	.13 Fe <sup>+</sup> , $\odot$ o, sp. - 1; .23 Fe, $\odot$ 3, sp. 3
82.397	8	4	31	4	.41 Fe, $\odot$ 5, sp. 6; .44 Nd <sup>+</sup> indetermin.
82.705		1	16	1	.70 Ti, $\odot$ o, sp. 1; .80 $\odot$ o, sp. - 1
82.998	5	4	27	5	.01 Ca, $\odot$ 4, sp. 6
83.315	33	1	16	3	.26 $\odot$ ? - 1N
83.712		2	19	1	
83.955		0	14	1	.91 $\odot$ (Fe?) - 2N, sp. - 1
84.198	7	2	27	2	.20 Cr <sup>+</sup> , $\odot$ 2Nd?, sp. 1
84.476		1	15	1	.41 $\odot$ o, sp. o; .51 Nd <sup>+</sup> , $\odot$ - 1
84.797	36	-1	19	2	.68 Ni, $\odot$ 1, sp. 1; .84 $\odot$ 1, sp. o
84.963	23	1	17	2	.99 Ti, $\odot$ 2, sp. 3
84.842				1	Bl. of 2 prec. lines
85.210		1	13	1	.20 $\odot$ (Ni?) - 1, sp. - 1N
85.427	9	2	20	3	.37 Ce <sup>+</sup> , $\odot$ 1, sp. 1; .45 Fe, $\odot$ 3, sp. 4

\* Value given for two observations is .7 range  $\div$  2.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4285.969.....	$\pm$ 10	1	19	3	.83 Fe?, $\odot$ 1, sp. 1; .01 Ti, $\odot$ 2
86.447.....	1	1	30	2	.44 Fe, $\odot$ 3N, sp. 2; .51 Zr <sup>+</sup> ?
86.955.....	22	1	24	4	.89 Fe, $\odot$ 1, sp. 0; .98 Fe, .99 La <sup>+</sup> , $\odot$ 2, sp. 1
87.336.....	10	1	21	4	? and .41 Ti, $\odot$ 1, sp. 2
87.604.....	62	0	20	2	.58 Fe, $\odot$ -1, sp. -1
87.861.....	15			2	.89 Ti <sup>+</sup> , $\odot$ 2, sp. 1
88.065.....				1	.01 Ni, $\odot$ 1, sp. 1; .15 Fe, $\odot$ 1, sp. 2
87.932.....	7	6	35	4	Bl. of 2 prec. lines
88.271.....	30	0	20	2	.15 Fe?
88.522.....		1	13	1	.54 in $\alpha$ Persei
88.707.....	6	1	14	3	.74 $\odot$ 2N, sp. 2
88.909.....	8	1	15	2	.96 Fe, $\odot$ 1, sp. 2
89.085.....	27	2	19	2	.07 Ti, $\odot$ 2, sp. 4
89.365.....	14	2	34	5	.36 Ca, $\odot$ 4, sp. 6
89.762.....	7	3	27	5	.73 Cr, $\odot$ 5, sp. 8; .92 Ti, .93 Ce <sup>+</sup> , $\odot$ 1, sp. 2
90.215.....		5	18	1	.22 Ti <sup>+</sup> , $\odot$ 2, sp. 2
90.414.....		3	15	1	.38 Fe, $\odot$ 1, sp. 1
90.293.....	8	5	28	5	Bl. of 2 prec. lines
90.936.....	15	3	34	4	.87 Fe, $\odot$ 1; .93 Ti, $\odot$ 3
91.459.....	9	2	33	4	.46 Fe, $\odot$ 2, sp. 3
91.932.....	24	1	20	3	.98 Cr, $\odot$ 0, sp. 0
92.248.....	41	2	20	3	.13 Fe Pred., $\odot$ 2; .29 Fe, $\odot$ 2, sp. 2
92.142.....	10	2	60	2	Bl. of 2 prec. lines
92.681.....	35	0	19	4	
93.106.....	16	3	38	5	.04 $\odot$ 2; .12 $\odot$ 3
93.456.....	14	0	15	2	
93.814.....	14	1	25	3	.80 $\odot$ 0, sp. 1
94.088.....	8	6	42	7	.05 $\odot$ 2; .11 Ti <sup>+</sup> , .13 Fe, $\odot$ 5
94.743.....	7	2	20	6	.78 Sc <sup>+</sup> , $\odot$ 2, sp. 2, and?
95.140.....	14	1	24	5	.04 $\odot$ 3d?, sp. 2; .23 $\odot$ 3 Nd?, sp. 2
95.654.....	20	0	26	2	.61 Ca?, .75 Ti, $\odot$ 2, sp. 4
95.973.....	0	1	24	2	.90 Ni, $\odot$ 1, sp. 0; .05 La <sup>+</sup> , .07 Ce <sup>+</sup> , $\odot$ 0N
95.812.....	11	2		2	Bl. of 2 prec. lines
96.509.....	2	2		2	.56 Fe <sup>+</sup> , $\odot$ 3, sp. 2
96.760.....	22	2		2	.68 Ce <sup>+</sup> , $\odot$ 1, sp. 2; .74 Zr <sup>+</sup> ?, .78 Ce <sup>+</sup> , $\odot$ 0N
96.591.....	12	3	31	6	Bl. of 2 prec. lines; Fe <sup>+</sup> predominates
97.085.....	20	1	35	3	.96 $\odot$ 2; .05 Cr, $\odot$ 1; .21 $\odot$ 2; .29 $\odot$ 2
97.606.....	18	1	22	2	.75 Cr, $\odot$ 0, sp. 1
98.026.....	9	2	37	5	Bl. of 2 foll. lines
97.942.....		2		1	.98 $\odot$ ? 1
98.153.....		1		1	.04 Fe, $\odot$ 2; .20 $\odot$ 1, sp. 0
98.534.....	29	2	22	4	.53 Ni, $\odot$ -1
98.816.....	13	2	23	4	.82 Ni, $\odot$ 2, sp. 1
99.151.....	11	5	26	3	.99 Ca, $\odot$ 3, sp. 4; .14 Ti, $\odot$ 1, sp. 1; .25 Fe, $\odot$ 4, sp. 5
99.071.....	13	6	43	4	Bl. of 2 prec. lines
99.457.....	7	1	20	2	.37 Ce <sup>+</sup> , $\odot$ 0; .49 $\odot$ 0, sp. -1

TABLE IV—Continued

$\alpha$ CANIS MINORIS*					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4299.663.....	33	1	20	2	.64 Ti, $\odot$ 2, sp. 3
4300.022†.....	7	5	39	6	.83 $\odot$ 1N, sp. 0; .05 Ti <sup>+</sup> , $\odot$ 3; .22 Mn <sup>+</sup> ?, $\odot$ 0, sp. 0
00.458.....	48	2	25	2	.33 Ce <sup>+</sup> , $\odot$ 1N, sp. 0; .57 Ti, $\odot$ 2, sp. 3
00.780.....	10	1	18	3	.74 $\odot$ 0; .82 Fe, $\odot$ 1
01.102.....	5	2	23	3	.00 $\odot$ 2; .09 Ti, $\odot$ 4; .19 V <sup>+</sup> , Cr?, $\odot$ 1
01.356.....	17	0	21	2	.32 V <sup>+</sup> ?, $\odot$ 0, sp. 0
01.610.....	10	0	23	2	.50 $\odot$ 0N, sp. -1; .75 Zr <sup>+</sup> ?, $\odot$ 0 Nd?, sp. -1
01.908.....	11	3	24	4	.93 Ti <sup>+</sup> , $\odot$ 2, sp. 2
02.244.....	15	1	21	2	.19 Fe, $\odot$ 2, sp. 2; .30 Y, $\odot$ 2, sp. 2
02.549.....	9	3	20	5	.53 Ca, $\odot$ 4, sp. 7
02.902.....		2	12	1	.92 $\odot$ , 1N, sp. 1
03.152.....	6	2	26	5	.09 $\odot$ 0, sp. -1; .18 Fe <sup>+</sup> , $\odot$ 2, sp. 1
03.423.....	24	0	17	2	.43 $\odot$ 1N, sp. 0
03.163.....		2	60	1	Bl. of 3 prec. lines
03.809†.....	7	1	40	5	.61 Nd <sup>+</sup> , $\odot$ 1, sp. 1; .72 $\odot$ 0; .84 $\odot$ 2; .94 $\odot$ 4
04.260.....	14	1	24	4	.26 $\odot$ 1, sp. 1
04.562.....	16	2	26	6	.55 Fe, $\odot$ 2, sp. 1
04.470.....		3	48	1	Bl. of 2 prec. lines and .40 $\odot$ 1, sp. 0
05.143.....	25	1	25	5	.14 Ce <sup>+</sup> , $\odot$ 1, sp. 0; .2 Fe, $\odot$ 0, sp. 0, .32 $\odot$ 1, sp. 0 prob. present
05.486.....	20	2	21	5	.46 Fe, $\odot$ 3, sp. 4
05.852.....	20	3	28	5	.71 Sc <sup>+</sup> , $\odot$ 2, sp. 2; .91 Ti, $\odot$ 4
06.171.....	37	1	19	3	.15 $\odot$ 2N, sp. 3
06.734.....	11	2	37	6	.58 Fe, $\odot$ 0, sp. 0N; .73 Ce <sup>+</sup> , $\odot$ 2, sp. 2; .86 $\odot$ 2, sp. 1
07.371.....	5	1	21	3	.31 $\odot$ ? 2 Nd?, sp. 1
07.819.....	10	7	41	7	.74 Ca, $\odot$ 3, sp. 4; .86 Ti <sup>+</sup> , .91 Fe, $\odot$ 6, sp. 7
08.145.....	6	0	18	2	
08.480.....	5	0	19	5	
08.907.....	8	1	21	3	.92 Zr <sup>+</sup> , $\odot$ 1, sp. 0
09.147.....		0		1	.04 Fe, $\odot$ 2; .13 $\odot$ 0; .21 $\odot$ (Fe?) 0
09.014.....	13	2	34	4	Bl. of 2 prec. lines
09.378.....	13	2	29	5	.38 Fe, $\odot$ 3, sp. 3; .46 $\odot$ 1, sp. 0
09.666.....	14	2	24	5	.63 Y <sup>+</sup> , $\odot$ 1, sp. 0; .74 Ce <sup>+</sup> , $\odot$ 1, sp. 0
09.500.....	16	4	45	3	Bl. of 2 prec. lines
10.213.....	48	0	26	2	.11 $\odot$ 2, sp. 0; .23 $\odot$ 1, sp. 0
10.535.....		1	30	1	.38 $\odot$ 2; .47 $\odot$ 1; .56 $\odot$ 0
10.793.....		-1	16	1	.71 V <sup>+</sup> ?, $\odot$ 2N, sp. 3d?; .90 $\odot$ 1, sp. 0
11.114.....	28	0	23	4	.99 $\odot$ 1, sp. 0; .17 $\odot$ 2, sp. 2
11.539.....	22	0	24	3	.53 Fe, $\odot$ 2
11.333.....	7	-1	b	2	Bl. of 2 prec. lines and .44 Fe, $\odot$ 2
11.705.....		-1	28	1	.72 $\odot$ 2N, sp. 2
11.892.....	18	0	21	4	

† Vi. wkr.

‡ Poor.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4312.148		1	24	1	.09 $\odot$ 2; .15 $\odot$ 1
12.304	3	0	31	2	.30 $\odot$ 2, sp. 1
12.868	7	4	30	7	.87 $Ti^+$ , $\odot$ 3, sp. 3
13.307	18	0	22	4	
13.645	20	0	30	4	.63 $\odot$ 2Nd?, sp. 1
14.084	10	6		2	.12 $Sc^+$ , $\odot$ 3, sp. 3
14.293		2		1	.22 $\odot$ 1, sp. 1; .34 $Ti$ , $\odot$ 1, sp. 2
14.112	5	6	51	6	Bl. of 2 prec. lines
14.500		-3	n	1	.51 $Nd^+$ , $\odot$ oN, sp. -1
14.882		4		1	.80 $Ti$ , $\odot$ 1, sp. 4; .98 $Ti^+$ , $\odot$ 3, sp. 3
15.158		4		1	.09 $Fe$ , $\odot$ 4, sp. 5
14.987	4	7	45	7	Bl. of 2 prec. lines
15.596	18	0	20	6	.57 $Cr^2$ , $\odot$ -1N, sp. -1
15.919	27	0	25	5	.9 $La^+$
16.323	16	-1	30	5	.22 $V^+$ ?
16.794	14	2	40	6	.81 $Ti^+$ , $\odot$ 1, sp. 0
17.077		-1	12	1	.97 $\odot$ ? o, sp. 0; .07 $\odot$ o, sp. 0
17.394	15	1	20	5	.31 $Zr^+$ , $\odot$ oN, sp. ob; and ?
17.702		0	15	1	.72 $\odot$ oN, sp. -1
18.100	13	0	25	3	.07 $\odot$ oN, sp. -1
18.366		1		1	.36 $\odot$ oNd?, sp. 0
18.650	3	4	41	7	.63 $Ti$ , .64 $Ca$ , $\odot$ 4, sp. 6
18.933	14	0	20	2	.95 $Sa^+$ , $\odot$ -1, sp. -2
19.154	25	0	15	4	
19.392		0	n	1	.45 $Fe$ Pred., $\odot$ o, sp. 0
19.552	7	0	14	3	.54 $Ca^2$ ; .65 $Cr^2$ , $\odot$ o, sp. 1
19.840	46	0	20	2	
20.379	37	1	24	4	.38 $\odot$ ( $Fe$ ) o, sp. -1; .50 $\odot$ ? o, sp. 1
20.745	15	5		2	.74 $Sc^+$ , $Ce^+$ , $\odot$ 3, sp. 3
21.028	31	2		2	.97 $Ti^+$ , $\odot$ 2, sp. 1
20.803	4	5	46	7	Bl. of 2 prec. lines
21.428	25	1		3	.42 $\odot$ oN
21.772	14	1	38	6	.67 $Ti$ , $\odot$ o, sp. 1; .80 $Fe$ , $\odot$ 2, sp. 2;
					.02 $V^+$ ?, $\odot$ oN
22.192	11	1	15	2	.22 $Ti^?$ , $\odot$ -1N
22.513	34	-1	22	2	.52 $La^+$ , $\odot$ oN
23.107	33	1	35	3	.01 $\odot$ 1; .06 $\odot$ o; .23 $\odot$ 2 Nd?, sp. 1;
					.29 $Sa^+$
23.592	5	0	20	2	.51 $Cr$ , $\odot$ 1; .61 $\odot$ o
23.356	31	1	78	5	Bl. of 2 prec. lines; probl. also .37 $Fe$ Pred.
23.833	44	0	17	2	.85 $\odot$ 3, sp. 2
24.038		0		1	.98 $\odot$ 1, sp. 0; .09 $\odot$ o, sp. 0
23.956	22	1	32	3	Bl. of 2 prec. lines
24.373	19	0	30	4	.41 $\odot$ 2N, sp. 2
24.972	7	4	39	7	.96 $Fe$ ; .00 $Sc^+$ , $\odot$ 4, sp. 5; .82 $\odot$ o, sp. -1
					prob. present
25.327	35	1	17	2	.36 $\odot$ ( $-Ni$ ) 1, sp. 1
25.771	3	6	49	7	.77 $Fe$ , $\odot$ 8, sp. 8; .76 $Nd^+$ ?
26.429	26	0	20	5	.35 $Ti^?$ , $\odot$ o, sp. 1

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4326.754	$\pm$ 10	1	20	4	.71 $Mn^{+?}$ ; .76 $Fe$ , $\odot$ 2, sp. 2
26.642	12	1		3	Bl. of 2 prec. lines
27.004	13	2	35	5	.97 $Ti$ , $\odot$ 2, sp. 1; .10 $Fe$ , $\odot$ 3, sp. 2
27.500	31	0		2	
27.892	17	1	32	6	.92 $Fe$ , $\odot$ 2, sp. 2; $Nd^{+}$ indetermin.
28.518	6	-1		2	
28.700	40	-1		2	
29.107	8	-2		2	.03 $Sa^{+}$ , $\odot$ -1
29.768	22	-1		2	
29.971		0		1	.03 $V$ , $\odot$ 0N, sp. 2
30.261		1		1	.26 $Ti^{+}$ , $\odot$ 1, sp. -1
30.194	21	1	30	5	Bl. of 2 prec. lines
30.425		0	14	1	.41 $\odot$ 0; .45 $Ce^{+}$ , $\odot$ 0
30.707	9	2	37	5	.71 $Ti^{+}$ , $\odot$ 2, sp. 1
31.040	13	0	15	2	.96 $Fe^{?}$ , $\odot$ 1, sp. 1
31.416				1	.45 $\odot$ 0N, sp. -1
31.767				1	.64 $Ni$ , $\odot$ 2, sp. 2; .75 $V^{+}$ , $\odot$ -1N, sp. 0
31.622	16	1	40	5	Bl. of 2 prec. lines
32.611	52	0		2	.57 $Cr$ , $\odot$ 0N, sp. -1
32.836	4	0		2	.83 $V^{?}$ , $\odot$ 0, sp. 2; .92 $\odot$ 0, sp. 0
33.792	29	-1	31	4	.77 $La^{+}$ , $\odot$ 1N, sp. 1
34.140	4	-2		2	.17 $Sa^{+?}$ , $\odot$ -1
34.608	60	0	25	2	.67 $\odot$ 0, sp. -1
34.855		0		1	.81 $V^{+?}$ - $Ti$ , $\odot$ 0, sp. 1; .87 $Ce^{+?}$
35.104		0	n	1	.98 $La^{+?}$ , $\odot$ 0, sp. 0; .275 $\odot^{?}Nd^{?}$ , sp. 1
35.764	26	0	22	2	.79 $\odot$ -1N
36.175	30	-1		3	.14 $V^{?}$ , $\odot$ -3; .25 $Ce^{+}$ , $\odot$ -1
36.440	24	0	18	2	
36.766	8	-1	24	2	
37.086	11	2	33	7	.05 $Fe$ , $\odot$ 5, sp. 7; .32 $Ti^{+?}$
37.600	9	2	22	6	.57 $Cr$ , $\odot$ 3, sp. 4; .60 $Zr^{+?}$
37.925	10	2	24	7	.92 $Ti^{+}$ , $\odot$ 4, sp. 4
38.145	7	1	15	3	.13 $Mn$ , $\odot$ -1
37.844	6	4	65	2	Bl. of 3 prec. lines
38.303		1		1	.27 $Fe$ , $\odot$ 1, sp. 1
38.583	31	1		2	.48 $Ti$ , $\odot$ 0d?, sp. 0; .70 $Nd^{+}$ , $\odot$ 0
39.395	32	2	20	2	.45 $Cr$ , $\odot$ 4, sp. 6
39.702	26	1	20	2	.72 $Cr$ , $\odot$ 3, sp. 4
39.550	26	1	43	2	Bl. of 2 prec. lines
40.431	13	§	§	7	.466 $H\gamma$ , $\odot$ 20, sp. 3
41.369	16	1	30	5	.25 $Fe$ , $Gd^{+?}$ , $\odot$ -1, sp. -2; .37 $Ti^{+}$ , $\odot$ 2, sp. 1
41.798	32	0	22	2	.70 $Fe$ , $\odot$ 0, sp. -1; .83 $\odot$ 0
42.081	24	0	22	3	.07 $Nd^{+?}$
42.511	38	1	13	2	
42.770	43	1	17	2	

§  $H\gamma$  varies considerably in intensity and width. On B 467,  $H\gamma$  is sharp and only about  $\frac{1}{2}$  Å wide, with estimated intensity of 15. On B 881 there is very much more and very broad absorption, extending from  $\lambda$  4337 to  $\lambda$  4345, with measurable lines toward the violet of 4339 and toward the red of 4343.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4342.601		1		1	Bl. of 2 prec. lines
43.211	20	1	32	5	.18 Cr, $\odot$ 2; .27 Fe, $\odot$ 2
43.660	11	1	22	5	.50 $\odot$ oN, sp. -1; .70 Fe, $\odot$ 2, sp. 3
43.988	31	-1	20	2	.02 Mn <sup>+</sup> ?, $\odot$ 1N, sp. 1
44.288		1		1	.29 Ti <sup>+</sup> , $\odot$ 2, sp. 1
44.540		1		1	.51 Cr, $\odot$ 4, sp. 6
44.394	8	3	47	6	Bl. of 2 prec. lines
44.974	6	0	20	3	.89 $\odot$ o, sp. 0; .09 Cr?, $\odot$ -1, sp. 0
45.354	40	1	30	3	
45.866	57	0	30	2	.87 Sa <sup>+</sup> , $\odot$ o, sp. 0
46.210		0	20	1	.30 Mn <sup>+</sup> , $\odot$ 1, sp. 1
46.578	12	1	36	5	.56 Fe, $\odot$ 2, sp. 2
46.878	42	0	15	2	.83 Cr, $\odot$ 1, sp. 1
47.210	76	-1		2	.24 Fe, $\odot$ 1, sp. 2
47.883	17	0	50	6	.81 Sa <sup>+</sup> ; .85 Fe, $\odot$ 2, sp. 3; .98 $\odot$ 1N, sp. 1
48.304	15	1	24	4	.32 Fe Pred., $\odot$ 1, sp. 1; .43 Mn <sup>+</sup> ?
48.572		1	24	1	.64 Zr <sup>+</sup> ?
48.946	13	1	27	4	.95 Fe, $\odot$ 2, sp. 3
49.673	5	0	23	3	.79 Ce <sup>+</sup> ?, $\odot$ -1
50.002	28	0	24	4	.97 V <sup>+</sup> ?, $\odot$ -1d?
50.332	17	1	20	2	.25 $\odot$ o, sp. 0; .38 Ba?, $\odot$ -1N
50.801	11	1		2	.84 Ti <sup>+</sup> , $\odot$ 1, sp. 1
51.174	50	1		2	.06 Cr, $\odot$ 3, sp. 5; .21 Nd <sup>+</sup>
50.934	10	3	41	5	Bl. of 2 prec. lines
51.498	25	1	22	3	.55 Fe, $\odot$ 2, sp. 2
51.824	20	7	40	2	.77 Fe <sup>+</sup> , Cr, $\odot$ 5, sp. 7; .94 Mg, $\odot$ 5Nd?, sp. 4
51.782	6	7	63	6	Bl. of 2 prec. lines
52.222		1	20	1	.27 $\odot$ oN, sp. -1
52.410	4	0	20	4	
52.739	7	3	32	7	.74 Fe, $\odot$ 4, sp. 6
53.138	36	0	20	3	.18 $\odot$ -1N, sp. 0
53.359	8	-1	19	3	
53.672	29	-1	23	2	
54.080	35	-2	20	3	.95 Cr?, $\odot$ o, sp. -1; .07 Ti, $\odot$ -1, sp. 0; .27 $\odot$ oNd?, sp. -1
54.582	5	3	33	5	.40 La <sup>+</sup> ?, $\odot$ -1, sp. -1; .60 Sc <sup>+</sup> , $\odot$ 1, sp. 0; .76 Fe?, $\odot$ oN
55.128	10	2	20	7	.10 Ca, $\odot$ 2, sp. 3
55.397	3	0	24	2	.35 Ti?, $\odot$ o, sp. 0
55.738	25	1	18	2	.71 $\odot$ o, sp. 0
56.016		1	25	1	.91 Ni?, $\odot$ o; .02 Nd <sup>+</sup> ?, $\odot$ o
56.356	28	1	22	2	.37 $\odot$ o, sp. -1
56.748	22	0	46	3	.61 Mn, $\odot$ o, sp. 0; .74 Cr?, $\odot$ -1, sp. 0; .91 Co?, $\odot$ o, sp. 0
57.084	26	0	17	2	.12 Fe?
57.513	30	0	35	5	.30 $\odot$ ? -1, sp. -1; .52 Cr, $\odot$ oNd?, sp. 0; .66 Mn?

|| Poor.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4357.940.....	$\pm$ 17	1	22	4	
58.214.....		0	n	1	.17 $Nd^+$ , $\odot$ o, sp. o
58.478.....	6	3	32	5	.51 $Fe$ , $\odot$ 2, sp. 2
58.782.....	20	2	22	5	.74 $Y^+$ , $\odot$ o, sp. 1
58.594.....	14	4	60	5	Bl. of 2 prec. lines
59.103.....	30	0	30	3	
59.438.....		1		1	.50 $\odot$ ? o
59.074.....		3		1	.63 $Cr$ , $\odot$ 3; .74 $Zr^+$ , $\odot$ o, sp. -1; .59 $Ni$ indeterm.
59.627.....	6	4	43	7	Bl. of 2 prec. lines
60.097.....	9	0	19	3	
60.415.....	10	1	21	3	.29 $\odot$ 1, sp. 1; .49 $Ti$ , $\odot$ 1, sp. 2
60.789.....	21	1	24	4	.73 $Sa^+$ ; .81 $Fe$ , $\odot$ 1, sp. 1
61.182.....	8	1	30	2	
61.467.....	2	1	21	2	
61.806.....		0	17	1	.80 $\odot$ -1N
62.076.....	12	0	26	4	.06 $Sa^+$ , $\odot$ -2; .11 $Ni^+$ , $\odot$ o, sp. 1
62.534.....	10	1	27	4	.54 $\odot$ 1, sp. 1
62.747.....		0	17	1	.75 $\odot$ oN, sp. o
63.124.....	13	0	23	4	.14 $Cr$ , $\odot$ 1N, sp. 2
63.370.....		0	17	1	.30 $\odot$ , oN, sp. 1; .47 $\odot$ o, sp. 1
63.575.....		1	n	1	.61 $\odot$ (- $Mo^+$ ?) o, sp. o
63.934.....	30	-1	20	3	.01 $I^{+2}$ , $\odot$ 1, sp. 1
64.194.....		-1	19	1	.17 $I^{+2}$ , $\odot$ 1, sp. 1
64.497.....		-1	22	1	.50 $\odot$ -1N, sp. -2
64.794.....	20	0	20	4	
65.144.....	7	-1	24	4	
65.370.....	30	0	20	2	.29 $Mn^{+2}$ , $\odot$ -1N
65.573.....	24	0	20	4	.54 $\odot$ o, sp. o
65.900.....	11	1	20	5	.90 $Fe$ , $\odot$ 2, sp. 2
65.814.....		2	45	1	Bl. of 2 prec. lines
66.176.....	40	0	14	3	
66.476.....	38	0	32	2	Bl. of 2 foll. lines
66.344.....	31	0		2	.35 $Nd^{+2}$ , $\odot$ -1, sp. o
66.513.....	2	1	20	2	.50 $\odot$ 1, sp. 1
66.694.....	47	-1	24	2	.68 $\odot$ 1, sp. 1
66.904.....	25	1	27	5	.95 $V^{+2}$
67.650.....	10	5	42	7	.58 $Fe$ , $\odot$ 5, sp. 5; .66 $Ti^+$ , $\odot$ 2, sp. o
68.003.....	40	-1		3	.91 $Fe$ , $\odot$ 2, sp. 3; .13 $\odot$ o, sp. 1
68.354.....	39	1	23	3	.30 $\odot$ ( $Ni$ ) o, sp. o
68.715.....	19	0	50	3	Bl. of 2 foll. lines
68.595.....	5	0	20	2	.63 $Nd^+$ , $\odot$ o, sp. o
68.871.....	23	0	20	3	.90 $\odot$ ( $Mn$ ?) -1d?, sp. o
69.165.....	5	1	22	2	.10 $V?$ ; $\odot$ -1
69.409.....	18	2	26	3	.41 $Fe^+$ , $\odot$ 1, sp. -1
69.774.....	8	3	44	4	.68 $Ti$ , $\odot$ o; .78 $Fe$ , $\odot$ 4
69.615.....	22	4	73	3	Bl. of 2 prec. lines
70.170.....	7	0	25	2	.16 $\odot$ o, sp. o
70.419.....	23	0	22	5	

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4370.891	$\pm$ 15	1	23	5	.86 Mn <sup>2</sup> , $\odot$ -2; .95 Zr <sup>+</sup> , $\odot$ 1
71.083		1		1	Bl. of .06 $\odot$ and .13 V <sup>+</sup> Pred.?
71.202	15	3	45	6	Bl. of prec. line; .28 Cr, $\odot$ 2, sp. 4; .43 $\odot$ o Nd <sup>2</sup> , sp. -2
71.914	45	0	22	3	
72.164	22	0	23	3	.20 Ni <sup>2</sup> , $\odot$ -2
72.410	34	0	16	2	.38 Ti, $\odot$ o, sp. 1
72.612	28	1	17	2	
72.780		0	18	1	.74 $\odot$ o, sp. -1; .85 $\odot$ o, sp. -1
73.027	4	1	22	2	.99 Fe, $\odot$ o, sp. o
72.880	13	1		2	Bl. of 2 prec. lines
73.363	29	1	20	3	.27 $\odot$ (Cr?) 1, sp. 3
73.701	4	1	22	3	.57 Fe, $\odot$ 2, sp. 2; .82 Ce <sup>+</sup> ?
73.568	5	2	43	3	Bl. of 2 prec. lines
74.162	36	2	25	3	.17 Cr, $\odot$ 1, sp. 1; .23 $\odot$ 1, sp. 1
74.455	10	3	20	3	.46 Sc <sup>+</sup> , .50 Fe <sup>2</sup> , $\odot$ 3, sp. 3
74.359	12	5	44	5	Bl. of 2 prec. lines
74.923	6	5	39	7	.83 Ti <sup>+</sup> , $\odot$ o, sp. -1; .96 Y <sup>+</sup> , $\odot$ 2, sp. 3; .99 Nd <sup>+</sup> ?
75.498	10	1	22	4	
75.930	6	4	38	7	.93 Fe, $\odot$ 6, sp. 9. Ce <sup>+</sup> indetermin.
76.717	16	0	26	6	.57 $\odot$ oN, sp. o; .78 Fe, $\odot$ 1, sp. 2
77.119	23	-1	25	4	.24 $\odot$ ? 2N, sp. 1
77.344	14	0	30	2	.37 Fe Pred. ?, $\odot$ od?, sp. 1
77.757	8	0	29	4	.80 Fe, $\odot$ 1, sp. 2; and .76 Mo <sup>+</sup> ?
78.190	16	0	29	3	.23 Sa <sup>+</sup> ?, .26 $\odot$ 2Nd <sup>2</sup> , sp. 2
78.621	0	0	21	2	
78.875	41	1	25	3	.92 $\odot$ 1N, sp. 1
79.284		2	32	1	.24 V, $\odot$ 4, sp. 8
79.186	11	2	50	4	Bl. of 2 prec. lines
79.760	6	1	29	4	.74 Mn <sup>+</sup> ?, .77 Zr <sup>+</sup> , $\odot$ o, sp. 1
80.140	5	0	22	2	.07 $\odot$ (Co?) 2Nd <sup>2</sup> , sp. 2
80.430	16	0	17	4	.50 $\odot$ o, sp. o
80.748	10	0	26	4	.73 $\odot$ 2Nd <sup>2</sup> , sp. 1; .85 $\odot$ ? -1d?, sp. -1
80.592		1	40	1	Bl. of two prec. lines
81.100	4	-1	25	2	.10 Mn <sup>2</sup> ; .12 Cr, $\odot$ o, sp. 1
81.618	2	0	20	2	.66 Mo?
81.874		0	10	1	.89 $\odot$ -1
82.080	2	0	26	2	.00 $\odot$ -1; .17 Ce <sup>+</sup> , $\odot$ -1
81.974		0	37	1	Bl. of 2 prec. lines
82.504	20	0	25	2	.52 $\odot$ o, sp. o
82.744	50	1	26	2	.69 $\odot$ o; .78 Fe, $\odot$ 2; .74 Nd <sup>+</sup> indetermin.
82.763	22	1	45	5	Bl. of 2 prec. lines?
83.032	32	1	24	2	.00 $\odot$ oN, sp. o
83.260	10	0	20	2	
83.533	8	8	41	7	.55 Fe $\odot$ 15, sp. 15
84.249	10	2	31	6	.13 $\odot$ oN, sp. o; .32 $\odot$ (Sa <sup>+</sup> ?) 1, sp. o

|| Poor.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4384.772 <sup>†</sup> .....	$\pm$ 12	3	40	7	.64 $Mg^+$ ; .73 $V$ , $\odot$ 3; .80 $Sc^+$ , $\odot$ 0; .98 $Cr$ , $\odot$ 2, sp. 4
85.185.....	37	1	25	3	.13 $\odot$ 1, sp. 0; .18 $La^{+?}$ ; .26 $Fe$ , $\odot$ 1, sp. 1
85.442.....	12	3	20	3	.39 $Fe^+$ , $\odot$ 2, sp. 0
85.370.....	14	3	48	6	Bl. of 2 prec. lines
85.962.....	18	—1	19	2	
86.213.....	45	—1	30	3	Absorption real; meas. uncertain
86.860.....	10	2	42	7	.86 $Ti^+$ , $\odot$ 1, sp. 0
87.373.....	16	1	18	5	.40 $\odot$ 0, sp. 0
87.572.....	32	1	20	2	.50 $\odot$ 0, sp. 1; .61 $\odot$ 0, sp. 0
87.880.....	13	2	29	7	.90 $Fe$ , $\odot$ 2, sp. 2
88.408.....	11	3	37	7	.42 $Fe$ , $\odot$ 3, sp. 3
88.980.....	14	0	25	3	
89.304.....	5	0	31	5	.25 $Fe$ , $\odot$ 2, sp. 3
89.655.....	16	0	24	3	
90.000.....	8	1	28	3	.99 $V$ , $\odot$ 2, sp. 5
89.985.....	19	1	49	4	Bl. of 2 prec. lines
90.493.....	10	0	30	4	.46 $Fe$ , $\odot$ 1, sp. 2; .54 $\odot$ 0, sp. 0; .59 $Mg^{+?}$
91.002.....	11	3	33	7	.96 $Fe$ , $\odot$ 2, sp. 3; .02 $Ti^+$ , $\odot$ 1, sp. 1
91.517.....	21	0		3	
91.838.....	36	1		3	.66 $Ce^+$ , $\odot$ 0; .76 $Cr$ , $\odot$ 1; .89 $Co?$ , $\odot$ 0
91.714.....	5	2	40	5	Bl. of 2 prec. lines
92.113.....	20	0	16	4	.07 $\odot$ (— $V$ ) 1N, sp. 2
92.371.....	17	1	22	3	
92.611.....	17	0	28	5	.57 $Fe$ Pred., $\odot$ 1, sp. 1
93.008.....	19	0	22	3	.93 $\odot$ —1, sp. —1; .04 $\odot$ 0, sp. 1
93.305.....	24	1	26	3	.28 $\odot$ 0, sp. 1
93.524.....	31	1	25	2	.53 $\odot$ ( $Cr$ ) 1Nd?, sp. 0
94.050**.....	5	3	41	7	.82 $\odot$ 0, sp. 0; .93 $Ti$ , $\odot$ 0, sp. 1; .06 $Ti^+$ , $\odot$ 2, sp. 1
94.355.....		—2	17	1	
94.581.....	22	0	20	4	
95.041.....	8	6	42	7	.03 $Ti^+$ , $\odot$ 3, sp. 2; .24 $V$ , $\odot$ 2, sp. 4
95.418.....	18	2	25	3	.51 $Fe?$ , $\odot$ 0, sp. —1
95.844.....	7	2	28	7	.85 $Ti^+$ , $\odot$ 1, sp. —1
96.103.....		—1	n	1	
96.328.....	10	—1	22	6	.31 $\odot$ 0, sp. 0
96.886††.....		1	30	2	.96 $\odot$ 1N, sp. 0
97.220.....	25	—1		3	.15 $Ni?$ , $\odot$ —1; .27 $Cr?$ , $\odot$ —1, sp. 0
97.995.....	16	2	30	5	.05 $Y^+$ , $\odot$ 1, sp. 1
98.316.....	10	1	26	4	.31 $Ti^+$ , $\odot$ 0, sp. —2
98.105.....	21	2	56	2	Bl. of 2 prec. lines
98.760.....	20	0	24	6	
99.216.....	22	—1	35	6	.07 $\odot$ —1N, sp. 0; .21 $Ce^+$ , $\odot$ —1; .29 $\odot$ 0, sp. 0
99.754††.....	7	5	35	7	.60 $Ni$ , $\odot$ 0, sp. —1; .77 $Ti^+$ , $\odot$ 3, sp. 2

† Prob. d.

†† V poor; d.?

\*\* Vi. wkr.

†† Vi. h.

THE SPECTRUM OF  $\alpha$  CANIS MINORIS

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TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4400.209		1		1	.19 $\odot$ o Nd?, sp. -1
00.402	6	4	40	7	.39 Sc <sup>+</sup> , $\odot$ 3, sp. 2
00.935	17	1	21	6	.86 $\odot$ (Nd <sup>+</sup> -Ni) oN, sp. o; .03 $\odot$ 1N, sp. 1
01.166	24	3		2	.03 $\odot$ 1N, sp. 1; .30 Fe, $\odot$ 2, sp. 2
01.488	17	5		2	.45 Fe, $\odot$ 1, sp. 1; .55 Ni, $\odot$ 2, sp. 4
01.420	9	5	49	7	Bl. of .30 Fe, .45 Fe, .55 Ni
02.134	8	0	23	5	
02.487	25	0	27	6	
02.785	29	1	28	4	
03.166	18	1	29	5	.08 $\odot$ -1, sp. -1; .19 $\odot$ 1, sp. o
03.416	15	0	25	2	.38 $\odot$ (Zr <sup>+</sup> ?-Cr) o, sp. 1; .50 Cr, $\odot$ -1, sp. -1
03.740	6	-1	21	3	
03.934		0	17	1	.98 $\odot$ o, sp. -2
04.106	18	-1	30	5	Bl. of .98 $\odot$ , .10 Fe Pred., and .28 Ti?
04.436	8	1		2	.40 Ti, $\odot$ -1, sp. o
04.753	5	7	46	7	.75 Fe, $\odot$ 10, sp. 10
05.214	20	0	18	4	
05.466	13	-2	20	2	.42 Fe Pred., $\odot$ -1
05.711	26	1	32	3	.74 $\odot$ oNd?, sp. -1
06.066	22	-1	29	4	.04 $\odot$ (Cr-)-1, sp. -1; .16 Fe?, $\odot$ o, sp. o Pd?
06.589	14	0	27	6	.65 V, $\odot$ 2, sp. 5
06.916	10	1	33	3	
07.125	2	0	22	2	
07.674	10	3	40	7	.66 V; .68 Ti <sup>+</sup> , $\odot$ 2; .72 Fe, $\odot$ 4
08.110	34	1	20	3	.08 Mn?; .21 V, $\odot$ 2, sp. 4
08.414	57	4		2	.42 Fe, $\odot$ 3; .51 V, $\odot$ 2
08.403	5	4	46	6	Bl. of 2 prec. lines
08.835	7	0	20	3	.83 Pr <sup>+</sup> ?, $\odot$ -1N
09.152	23	2	29	6	.12 Fe, $\odot$ 1, sp. 2; .24 Ti <sup>+</sup> , $\odot$ o, sp. -2
09.534	14	2	36	6	.54 Ti <sup>+</sup> , $\odot$ 1, sp. o; .37 Sa <sup>+</sup> prob. present
09.326	20	2	75	2	Bl. of 2 prec. lines
10.083	33	1	22	4	.01 $\odot$ ? oN, sp. o
10.471	26	1	30	6	.31 Cr, $\odot$ -1N, sp. o; .50 Ni, $\odot$ 2, sp. 2
10.823		1		1	.77 Ti?, $\odot$ -3; .86 $\odot$ -1
11.084	10	2	32	7	.08 Ti <sup>+</sup> , $\odot$ 1, sp. 1; .06 Nd <sup>+</sup> indetermin. but prob. present
11.880	16	2	36	4	.88 Mn?, $\odot$ -2; .95 Ti <sup>+</sup> , $\odot$ 1, sp. o
12.359	33	0	28	4	.28 Cr, $\odot$ o, sp. 2; .42 Ti, $\odot$ -1N, sp. o
12.864	18	0	32	4	
13.594	12	2	42	6	.60 $\odot$ 1, sp. o
14.494	27	1	26	4	.53 Zr <sup>+</sup> , $\odot$ -1; and V?
14.810	22	2	20	4	.87 Mn, $\odot$ 2, sp. 2
15.138	14	5	25	5	.13 Fe, $\odot$ 8, sp. 8
15.064	10	5	52	4	Bl. of 2 prec. lines
15.587	10	2	29	7	.58 Sc <sup>+</sup> , $\odot$ 3, sp. 3
16.027	8	0	17	3	
16.249	22	1	25	4	.28 [Fe II]?

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4416.507.....	$\pm$ 32	0	27	3	.48 $V?$ , $\odot$ 0, sp. 3; .54 $Ti?$
16.808.....	11	4	35	7	.81 $Fe^+$ , $\odot$ 2, sp. 0
17.358.....	15	1	22	6	.28 $Ti$ , $\odot$ 0, sp. 1; .42 $\odot$ -1
17.727.....	11	4	34	7	.73 $Ti^+$ , $\odot$ 3, sp. 2
18.321.....	5	3	32	7	.34 $Ti^+$ , $\odot$ 1, sp. 0; .43 $Fe?$ , $\odot$ -1, sp. 0
18.709.....	27	-1	22	4	? and .72 $Ce^+$ , $\odot$ -1
18.976.....	9	0	21	3	
19.211§§.....	38	-2	28	3	
19.476.....		-2	n	1	.52 $Fe?$ , $\odot$ -1
19.767.....	20	-1	35	4	.78 $Mn^+$ , $\odot$ -1N, sp. -1
20.204.....	8	-2		2	.29 $\odot$ 0, sp. -1
20.528.....	20	-1	25	2	.55 $Sa^+$ , $\odot$ -1, sp. 0; .66 $Sc?$ , $\odot$ -1, sp. -3
20.423.....	12	0	44	3	Bl. of 2 prec. lines
21.042.....	18	2	25	3	.14 $Sa^+$ , $\odot$ -1N; and ?
21.330.....	7	-2	22	2	.36 $Co?$ , $\odot$ -1, sp. ob
21.564.....	17	0	25	4	.58 $V?$ , $\odot$ 0, sp. 3
21.927   .....	10	2	34	6	.76 $Ti$ , $\odot$ -1, sp. 1; .95 $Ti^+$ , $\odot$ 1, sp. -1; .07 $\odot$ 0, sp. 0
22.552¶¶.....	6	3	37	7	.57 $Fe$ ; .61 $Y^+$ , $\odot$ 3, sp. 4
23.042.....	21	0	30	6	.82 $Ti?$ , $\odot$ 0, sp. 1; .98 $Ni$ , $\odot$ od?, sp. 0; .15 $Fe$ , $\odot$ 1, sp. 2
23.329.....	26	0	25	4	.22 $Ti^+$ Pred.?, .32 $Cr$ , $\odot$ oN, sp. 1d?
23.159.....	13	1	55	2	Bl. of 2 prec. lines
23.826.....	21	0	34	6	.68 $Ce^+$ , $\odot$ -2; .86 $Fe$ , $\odot$ 2, sp. 2; .07 $Cr$ , $\odot$ 0, sp. 0
24.288.....	20	0	34	4	.10 $Fe$ , $\odot$ -1, .28 $Cr$ , $\odot$ 0; sp. 2; .36 $Sa^+$ , $\odot$ -1
24.128.....		1	93	1	Bl. of 2 prec. lines
24.778.....		-1		1	.82 $\odot$ ( $Ni?$ )-1d?
25.122.....	25	0	20	3	.16 $Cr?$ , $\odot$ -2N
25.447.....	4	4	39	7	.44 $Ca$ , $\odot$ 4, sp. 6
25.752.....	17	1	15	2	.77 $\odot$ -1N, sp. -1
26.048.....	22	0	23	4	.05 $Ti$ , $\odot$ oNd?
26.367.....	16	0	27	5	
26.633.....		0	n	1	
26.966.....	25	0	23	2	
27.267.....	6	4	41	7	.10 $Ti$ , $\odot$ 2, sp. 3; .31 $Fe$ , $\odot$ 5, sp. 9
27.646.....	34	-1	20	2	.56 $La^+$ , $\odot$ -2; .71 $Cr?$ , $\odot$ -3
27.902.....	12	0	28	6	.90 $Ti^+$ Pred.; .92 $Ce^+$ , $\odot$ -1, sp. -1
28.477.....	22	0	33	3	.51 $Cr$ , $V?$ ; .57 $Fe$ Pred.?
29.254.....	11	-1	26	4	.25 $Pr?$ ; .27 $Ce?$
29.880.....		1		1	.91 $La^+$ , $Cr?$ , $\odot$ -1N, sp. 0
30.174.....	20	1		2	.20 $Fe$ , $\odot$ 1, sp. 1
30.060¶¶.....	12	2	50	5	Bl. of 2 prec. lines; .02 $Ti$ prob. present

§§ Absorption real; measure v. uncertain.

||| Seems to be d.(?) on B 467, with measures at .78 and .01. This may indicate the explanation for the apparently abnormally high intensity of this member of the  $Ti^+$  multiplet?

¶¶ Vi. wkr.?

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4430.626.....	7	3	39	7	.62 Fe, $\odot$ 3, sp. 4; .77 $\odot$ ? o, sp. -1
31.008.....	41	0	25	2	.02 $\odot$ -1, sp. -1
31.359.....	16	1	35	6	.35 Sc <sup>+</sup> , $\odot$ o, sp. ob
31.932.....	24	1	30	5	.85 $\odot$ o, sp. o; .91 Ba } .09 Ti <sup>+</sup> , $\odot$ -1,
32.240.....	22	0	26	5	.17 Cr?, $\odot$ o } prob. present
32.620***.....	12	1	30	4	.57 Fe, $\odot$ 1, sp. 1; .60 Ti?, .74 Cr?, $\odot$ -1N
33.238.....	7	3	42	7	.22 Fe, $\odot$ 3, sp. 3
33.806.....	12	2	36	7	.80 Fe, $\odot$ 1, sp. 2; .91 Sa <sup>+</sup> ?
34.403.....	16	1	28	6	.34 Sa <sup>+</sup> , $\odot$ -1, sp. o; .44 $\odot$ o, sp. -2
34.900.....	8	5	43	7	.96 Ca, $\odot$ 5, sp. 8; .15 Fe, $\odot$ 2, sp. 4
35.672.....	5	3	33	7	.68 Ca, $\odot$ 4, sp. 7
36.264.....	22	1	.....	3	.14 V, $\odot$ o, sp. 1; .36 Mn, $\odot$ 2, sp. 2
36.558.....	8	0	.....	2	.59 Ti, $\odot$ -1, sp. 1
36.340.....	12	1	37	4	Bl. of 2 prec. lines
36.942.....	10	2	31	7	.93 Fe, .98 Ni, $\odot$ 2d?, sp. 2
37.622.....	19	0	39	6	.57 $\odot$ (Ni?) o, sp. -2
38.130.....	41	0	20	2	.20 $\odot$ (-Ti) -1d?
38.342.....	18	1	28	5	.36 Fe, $\odot$ 1, sp. o
38.681.....	26	-1	27	3	.....
38.429.....	2	1	52	2	Bl. of 2 prec. lines
39.075.....	2	1	35	4	.17 $\odot$ ? oNd?
39.377.....	40	0	25	3	.....
39.631.....	15	0	25	2	.64 Fe, $\odot$ o, sp. o
39.926.....	19	0	28	6	.89 Fe, $\odot$ 1, sp. o
40.496†††.....	18	1	26	5	.35 Ti, $\odot$ -1, sp. 1; .44 Zr <sup>+</sup> ; .48 Fe, $\odot$ 1, sp. -1
40.953.....	22	1	32	6	.84 Fe, $\odot$ 1, sp. 1; .97 Fe, $\odot$ o, sp. o; .09 $\odot$ o, sp. -1
41.372.....	36	0	22	2	.27 Ti, $\odot$ -1, sp. o; .43 Ni?, $\odot$ -1
41.714.....	8	2	35	7	.69 V; .72 Ti <sup>+</sup> , $\odot$ 3 Nd?, sp. 5N
42.350.....	8	3	41	7	.35 Fe, $\odot$ 6, sp. 8
42.813.....	6	1	21	2	.84 Fe, $\odot$ 1, sp. 2
43.016.....	21	2	25	2	.09 Zr <sup>+</sup> , $\odot$ o, sp. o
42.916.....	7	2	.....	2	Bl. of 2 prec. lines
43.224.....	15	2	22	5	.20 Fe, $\odot$ 3, sp. 3
43.093.....	8	2	56	6	Bl. of .84 Fe, .99 Zr <sup>+</sup> , and .20 Fe
43.530†††.....	.....	-1	15	1	.56 $\odot$ -2N
43.815.....	3	5	36	7	.80 Ti <sup>+</sup> , $\odot$ 5, sp. 3
44.233.....	36	-1	22	2	.22 V, $\odot$ o, sp. 2
44.501.....	9	2	34	7	.56 Ti <sup>+</sup> , $\odot$ 2, sp. 1; .40 Ce <sup>+</sup> indetermin.
44.784.....	.....	-1	28	1	.70 Ce <sup>+</sup> , $\odot$ -1
44.996.....	13	-1	17	2	.....
45.287.....	36	-1	30	3	.....
45.520.....	42	0	29	3	.48 $\odot$ (Fe-) 1, sp. 2

\*\*\* R. ftr.

††† Measured as double on R 1987, at  $\lambda$  .30 and  $\lambda$  .53.

††† Real?

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4446.130.....	$\pm$ 30	—1	33	3	
46.432.....	70	0	27	2	.39 $Nd^+$ , $\odot$ —1
46.847.....	12	2	30	7	.85 $Fe$ , $\odot$ 2, sp. 2
47.199.....	14	1	30	7	.14 $Fe$ , .16 $Mn$ , $\odot$ 2, sp. 2
46.947.....	12	2	66	5	Bl. of 2 prec. lines
47.734.....	6	4	39	7	.73 $Fe$ , $\odot$ 6, sp. 7
48.370.....	26	—1	33	5	
48.700.....	14	—1	26	3	
48.901.....		—1	26	1	.95 $\odot$ ? —1N
49.115.....	22	1	22	3	.14 $Ti$ , $\odot$ 2, sp. 3
49.002.....	10			2	Bl. of 2 prec. lines
49.330.....	21	1	n	2	.34 $Ce^+$ , $\odot$ —1, sp. —1
49.484.....	2	0	20	2	.47 $\odot$ —1
49.182.....	10	2	63	4	Bl. of .9, .14 $Ti$ , .34 $Ce^+$ , .47 $\odot$
49.600.....	29	0	22	2	.72 $Dy^+$ , $\odot$ —1
50.018.....	26	0	28	2	.93 $\odot$ —1d?, sp. 0; .11 $\odot$ —1N
49.851.....	22	1	34	2	Bl. of .72 $Dy^+$ and .93 $\odot$
50.269.....		2		1	.32 $Fe$ , $\odot$ 1, sp. 1
50.529.....		4		1	.49 $Ti^+$ , $\odot$ 2, sp. 1
50.403.....	8	4	42	7	Bl. of 2 prec. lines
50.931.....	9	1	20	5	.89 $Ti$ , $\odot$ 1, sp. 2
51.282.....	20	—1	22	2	
51.576.....	4	2	32	6	.58 $Mn$ , $\odot$ 3, sp. 4; .57 $Nd^+$ indetermin.
51.911.....	11	—2		2	.99 $Nd^{+?}$ , $V^?$ , $\odot$ 0N, sp. 1
52.182.....	27	0	25	5	
52.603.....	30	1	30	4	.62 $\odot$ 0, sp. 0; .75 $Sa^{+?}$ , $\odot$ —1
53.002.....	12	1	40	5	.01 $Mn$ , $\odot$ 1, sp. 2
53.355.....	9	0		2	.31 $Ti$ , $\odot$ 2, sp. 4
53.724.....	21	0	27	2	.71 $Ti$ , $\odot$ 1, sp. 2
54.162.....	10	1		2	
54.398.....	9	3	29	7	.38 $Fe$ , $\odot$ 3, sp. 3
54.798.....	4	4	34	7	.78 $Ca$ , .80 $Zr^+$ , $\odot$ 5, sp. 8
54.614.....		4	72	1	Bl. of 2 prec. lines
55.078.....	6	—1	20	3	.04 $Fe$ , $Mn^?$ , $\odot$ 1, sp. 3
55.309.....	10	1	26	5	.32 $Ti$ , $Mn^?$ , $\odot$ 2, sp. 3
55.877.....	4	3	33	7	.82 $Mn$ , $La^{+?}$ , $\odot$ 2; .88 $Ca$ , $\odot$ 3
56.360.....	17	1	20	4	.34 $Fe$ , $\odot$ 1, sp. 1; .40 $Nd^{+?}$
56.644.....	22	1	21	4	.62 $Ca$ , .64 $Ti^+$ , $\odot$ 2, sp. 4
56.512.....	10	1	47	5	Bl. of 2 prec. lines
57.014.....	12	0	22	4	.04 $Mn$ , $\odot$ 0, sp. 1
57.492§§§.....	10	2	40	7	.41 $Zr^+$ ; .43 $Ti$ , $\odot$ 2, sp. 4; .55 $Mn$ , $\odot$ 2, sp. 3
58.029.....	19	2	20	4	.10 $Fe$ , $\odot$ 2, sp. 2
58.296.....	22	2	30	4	.26 $Mn$ , $\odot$ 2, sp. 3
58.174.....	7	2	51	5	Bl. of 2 prec. lines
58.567.....	15	0	20	2	.54 $Cr$ , $Sa^{+?}$ , $\odot$ 0, sp. 1
58.808.....	25	—1	20	2	.84 $\odot$ —1N

§§§ D.(?), equal.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4459.117 $\parallel\parallel\parallel\parallel$ .....	4	5	41	7	.05 Ni, $\odot$ 2; .12 Fe, $\odot$ 3; .36 Cr, $\odot$ 1, sp. 2
59.848 .....	24	0	34	3	.76 $\odot$ (Cr-V) 1, sp. 3; .90 $\odot$ -2
60.284 $\text{¶¶¶}$ .....	11	1	36	5	.21 Ce <sup>+</sup> , $\odot$ 0; .31 V, $\odot$ 1; .40 Mn, $\odot$ 0
60.527 .....	36	0	25	2	.54 $\odot$ -1d?
60.811 .....	45	-1	22	2	.78 Cr, $\odot$ -1, sp. -1
61.128 .....	12	2	40	6	.09 Mn, $\odot$ 1, sp. 2; .21 Fe, Zr <sup>+</sup> , $\odot$ 1, sp. 1
61.646 .....	14	3	44	7	.66 Fe, $\odot$ 4, sp. 7
62.001 .....	13	2	28	5	.01 Fe, .03 Mn, $\odot$ 3 Nd <sup>2</sup> , sp. 4
62.433 $\text{*****}$ .....	14	1	29	4	.37 V, $\odot$ -1, sp. 1; .46 Ni, $\odot$ 1, sp. 1; .42 Nd <sup>+</sup> indetermin.
63.074 .....	24	0	24	6	.99 Nd <sup>+</sup> and?
63.437 .....	21	0	28	7	.41 $\odot$ , (Ti, Ce <sup>+</sup> ), 0, sp. 1; .26 $\odot$ -1N, sp. -1. .54 Ti prob. present
63.902 .....	16	0	25	6	.....
64.474 .....	15	4	.....	2	.46 Ti <sup>+</sup> , $\odot$ 2, sp. 1
64.806 .....	3	2	.....	2	.68 Mn, $\odot$ 2; .77 Fe, $\odot$ 1
64.542 .....	7	4	57	6	Bl. of 2 prec. lines
65.274 .....	24	-1	30	6	.28 Y <sup>+</sup> , .35 Cr <sup>2</sup> , $\odot$ 0, sp. 1
65.780 .....	27	-1	30	5	.81 Ti, $\odot$ 1, sp. 2
66.061 .....	39	-2	n	2	(.17 Fe, Cr) <sup>2</sup> , $\odot$ -1N
66.539 .....	7	4	36	7	.42 Ni <sup>2</sup> , $\odot$ 0, sp. 0; .56 Fe, $\odot$ 5, sp. 7
66.995 .....	7	0	27	6	.94 Fe, $\odot$ 1, sp. 2
67.339 .....	24	0	21	4	.33 Sa <sup>+</sup> , $\odot$ -1, sp. -1
67.542 .....	29	0	19	2	.54 Ce <sup>2</sup> , Cr <sup>2</sup> , $\odot$ -1N, sp. 0
67.712 .....	20	0	21	2	.76 Ca?
67.937 .....	18	0	15	3	.....
68.156 .....	6	0	18	3	.....
68.487 .....	6	5	36	7	.49 Ti <sup>+</sup> , $\odot$ 5, sp. 3
69.130 .....	4	4	.....	2	.15 Ti <sup>+</sup> , $\odot$ 1, sp. 1
69.434 .....	14	3	.....	2	.38 Fe, $\odot$ 4, sp. 4
69.280 .....	8	4	54	7	Bl. of 2 prec. lines
69.586 .....	35	0	.....	2	.57 Co, $\odot$ 0d?, sp. -1
70.161 .....	14	0	28	5	.14 Mn, $\odot$ 1, sp. 1
70.493 .....	15	1	28	6	.48 Ni, $\odot$ 2, sp. 2
70.894 .....	10	2	30	5	.86 Ti <sup>+</sup> , $\odot$ 1, sp. 1
70.678 .....	16	.....	59	2	Bl. of 2 prec. lines
71.236 .....	22	0	26	4	.24 Ce <sup>+</sup> , Ti, $\odot$ 0, sp. 2
71.640 .....	20	0	22	4	.68 Fe Pred., $\odot$ 0, sp. 1; and .56 Co <sup>2</sup> , $\odot$ -1N
71.963 .....	6	1	25	3	.....
72.282 .....	15	1	28	4	.....
72.046 .....	24	.....	.....	2	Bl. of 2 prec. lines
72.561 .....	.....	1	.....	1	.54 Fe Pred., $\odot$ -1N
72.878 .....	21	2	.....	2	.72 Fe, Ce <sup>+</sup> , $\odot$ 1; .79 Mn, $\odot$ 0; .93 Fe <sup>+</sup> , $\odot$ 1, sp. 0
72.839 .....	7	3	43	6	Bl. of 2 prec. lines

 $\parallel\parallel\parallel$  R. fz. $\text{¶¶¶}$  D.?\*\*\*\* Presence of .20  $\odot$ <sup>+</sup> and .70  $\odot$ <sup>+</sup> indicated on R 1973.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4473.413.....	$\pm$ 12	0	21	4	.39 $\odot$ (Co?) - 2
73.723††††.....		-1		1	.77 Cr, $\odot$ -1
74.076.....	23	0	24	2	.05 V, $\odot$ -1, sp. 1
73.904.....	10	0		2	Bl. of 2 prec. lines
74.447.....	27	0	30	4	
74.744.....	20	0	36	3	
75.195.....	52	0	36	2	
76.036.....	3	4	39	7	.02 Fe, $\odot$ 4; .08 Fe, $\odot$ 3
76.595.....	18	-1	22	3	
76.857.....	10	1	24	3	
77.155.....	20	0	29	3	.07 Cr?, $\odot$ -1, sp. 0; .24 Co?, $\odot$ -2d?
77.461.....	21	0	30	6	.44 Y?, $\odot$ -1N, sp. -1
77.964.....	33	0	30	6	? and .03 $\odot$ 0, sp. 1
78.424.....	35	-1	33	4	
78.766.....	20	0	30	5	.68 Sa <sup>+</sup> ?; .74 Mn <sup>+</sup> ?
79.018.....	52	0	28	2	
79.544.....	12	1	40	6	.36 Ce <sup>+</sup> -Mn, $\odot$ 0, sp. -1; .61 Fe, $\odot$ 1, sp. 2; .72 Ti, $\odot$ -1, sp. 0
80.101.....	14	2	38	7	.97 $\odot$ (Al <sup>++</sup> ?) 0, sp. 0; .14 Fe, $\odot$ 1, sp. 3; .28 Fe, $\odot$ -1, sp. -1N
80.580.....	30	0	30	4	.50 $\odot$ (Ni-Ti) 0N, sp. 1
80.882.....	23	1	25	4	.83 $\odot$ 0, sp. 0
81.226.....	6	7	46	7	.13 Mg <sup>+</sup> , $\odot$ 0, sp. -2; .33 Mg <sup>+</sup> , $\odot$ 0, sp. -2; .26 Ti indetermin.
81.584.....	29	0	23	3	.62 Fe, $\odot$ 1, sp. 1
82.212.....	3	4	35	7	.18 Fe, $\odot$ 5; .26 Fe, $\odot$ 3
82.794.....	12	2	30	5	.60 Ti; .75 Fe, $\odot$ 1, sp. 2; .88 Cr, $\odot$ -1, sp. -2
83.238.....	13	-1	20	2	
83.466.....	55	1	30	2	
83.799.....	44	0	28	4	.78 $\odot$ 0, sp. 0; .90 Ce <sup>+</sup> , $\odot$ 0, sp. -1
84.261.....		2	26	1	.24 Fe, $\odot$ 4, sp. 4
84.166.....	8	3	49	6	Bl. of 2 prec. lines
84.578.....	41	0	22	3	
84.934.....	14	0	23	5	.96 Ca?
85.218.....	30	-1	20	2	
85.650.....	25	2	41	6	.68 Fe, $\odot$ 3, sp. 3
86.054.....	13	0	24	4	.98 $\odot$ ? 0, sp. -1
86.319.....	52	0	25	2	
86.828.....	37	0	38	3	? and .01 Ce <sup>+</sup> , $\odot$ 0, sp. 0
87.261.....	32	1	32	4	.27 Y, $\odot$ -1, sp. -2; .37 Fe, $\odot$ -1, sp. -1
87.820.....	6	0	34	3	
88.270.....	7	3	43	6	Bl. of 2 foll. lines
88.060.....	8	1		2	.14 Fe, $\odot$ 1, sp. 0
88.338.....	5	2		3	.32 Ti <sup>+</sup> , $\odot$ 1, sp. 0
88.806.....	6	1	22	2	.02 Fe, $\odot$ 1, sp. 1
89.178.....	8	3		2	.10 Ti, $\odot$ 0, sp. 2; .21 Fe <sup>+</sup> , $\odot$ 2, sp. 0

†††† Real?

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4489.086.....	$\pm$ 6	3	50	7	Bl. of 2 prec. lines
89.501.....	13	—2	.....	2	.47 Cr, $\odot$ 0, sp. 0
89.733.....	6	2	24	6	.74 Fe, $\odot$ 4, sp. 7
90.086.....	12	2	24	7	.08 Mn, .09 Fe, $\odot$ 3N, sp. 4
89.864.....	.....	3	.....	1	Bl. of 2 prec. lines
90.540.....	.....	1	.....	1	.53 Ni, $\odot$ 0, sp. —1
90.799.....	.....	2	.....	1	.78 Fe, $\odot$ 2, sp. 2
90.731.....	12	2	39	5	Bl. of 2 prec. lines
91.026.....	39	.....	.....	2	.....
91.416.....	5	4	31	7	.41 Fe <sup>+</sup> , $\odot$ 2, sp. 0
91.930.....	20	0	22	4	.....
92.375.....	22	0	28	5	.31 Cr, $\odot$ 0, sp. 1; .54 Ti, $\odot$ —1, sp. 0
92.800++++	27	—1	30	5	.69 Fe, $\odot$ 1, sp. 1 and ?
92.494.....	13	—1	.....	2	Bl. of 2 prec. lines
93.410++++	9	1	31	5	.40 Cr, $\odot$ —1, sp. 0
93.578++++	22	0	.....	2	.54 Ti <sup>+</sup> , $\odot$ 1, sp. 0
93.085.....	24	—1	25	5	.96 $\odot$ 0, sp. 0; .05 Fe Pred., $\odot$ 1, sp. 0
94.221.....	16	0	24	3	.19 $\odot$ —1N, sp. 0
94.567.....	4	4	35	7	.57 Fe, $\odot$ 6, sp. 9
95.085.....	.....	—1	16	1	.01 Ti, $\odot$ —1, sp. 0
95.430.....	16	1	25	4	.43 $\odot$ (Fe, Zr <sup>+</sup> , Ti <sup>+</sup> ) 0N, sp. 0
95.676.....	41	—1	24	2	.58 Fe <sup>2</sup> , $\odot$ 0, sp. 0
96.041.....	16	0	36	6	.97 Fe, $\odot$ 1, sp. 1; .15 Ti, $\odot$ 1
96.366.....	20	0	20	3	.....
96.870.....	9	4	38	7	.86 Cr, $\odot$ 3, sp. 6; .96 Zr <sup>+</sup> , $\odot$ 0, sp. 0
97.537.....	11	0	22	4	.....
97.860.....	32	0	38	3	.85 Ce <sup>+</sup> , $\odot$ —2
97.689.....	23	0	.....	2	Bl. of 2 prec. lines
98.851.....	24	2	36	3	.73 Cr, $\odot$ 0, sp. 1; .90 Mn, $\odot$ 1, sp. 2
99.186.....	48	1	27	2	.15 $\odot$ 1, sp. 1
98.992.....	20	1	61	4	Bl. of 2 prec. lines
99.579.....	.....	—1	41	1	.....
4500.341.....	9	1	34	5	.29 Cr, $\odot$ 0, sp. 1; and ?
00.786.....	15	—1	20	3	.....
01.277.....	7	6	43	7	.27 Ti <sup>+</sup> , $\odot$ 5, sp. 3; .10 Cr not indicated
01.732.....	.....	0	n	1	.78 Cr, $\odot$ 0 Nd <sup>2</sup> , sp. 1
01.030.....	.....	—2	n	1	.97 V <sup>2</sup> , $\odot$ —1N, sp. 0
02.114.....	23	1	30	4	.....
02.358.....	16	0	.....	2	.....
02.240++++	18	.....	.....	2	Bl. of 2 prec. lines—.22 Mn, $\odot$ 2, sp. 2, and ?
02.626.....	6	0	30	2	.59 Fe, $\odot$ 0, sp. 0
03.129.....	.....	0	27	1	.....
03.750§§§§	89	—1	35	2	.76 Ti, $\odot$ —1; .87 Mn, $\odot$ —1
04.286.....	44	0	24	2	.....
04.792.....	19	—1	27	4	.74 $\odot$ —1, sp. —1; .84 Fe, $\odot$ 1, sp. 1
05.866.....	47	—1	27	2	.....

++++ Poor.

§§§§ V. poor.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4506.785.....	$\pm$ 21	—1	21	5	.74 $Ti^+$ , $\odot$ —1, sp. ob; .85 $Cr$ , $\odot$ —1, sp. —1
07.264.....	28	0	20	5	.22 $Cr^+$ Pred., $\odot$ —1, sp. —1
07.564.....	26	—1	.....	3	.....
07.854.....	25	0	25	5	.76 $\odot$ —1, sp. 0; .86 $Ca$ , $\odot$ —1, sp. 0; .01 $\odot$ —1, sp. 0
08.282.....	4	4	40	7	.29 $Fe^+$ , $\odot$ 4, sp. 2
08.729.....	31	—1	30	5	.69 $\odot$ 0, sp. —1; .88 $Fe$ Pred., $\odot$ —2
09.103.....	31	—1	22	3	.14 $Fe$ Pred.?, $\odot$ —2
09.397.....	25	—1	30	5	.29 $\odot$ ( $Ni^+$ , $V^?$ ) oN, sp. 0; .45 $Ca$ , $\odot$ 0, sp. 1
09.776.....	25	—1	34	4	.74 $\odot$ 1, sp. 1; .8 $Fe$
10.082.....	39	—1	18	2	.....
10.438.....	59	—1	25	2	.....
10.880.....	.....	—1	.....	1	.82 $Fe$ , $\odot$ 0, sp. oN
11.915.....	17	1	25	3	.84 $Sa^+$ ; .91 $Cr$ , $\odot$ 1, sp. 2
12.275.....	40	1	34	3	.27 $Ca$ , $\odot$ 0, sp. 1
12.780.....	10	1	34	6	.73 $Ti$ , $\odot$ 3, sp. 6
13.216.....	21	—1	25	4	.....
13.476.....	27	0	23	2	.44 $\odot$ 0, sp. —3; .59 $\odot$ ( $Y^?$ ) —1, sp. 0
13.658.....	6	1	26	3	Bl.: .59 $\odot$ ; .71 $Ti$ ; .72 $Fe$ Pred.?
13.929.....	10	0	25	2	.90 $Ni$ , $\odot$ —2
14.174.....	23	1	.....	2	.19 $Fe$ , $\odot$ 1, sp. 2
14.377.....	.....	2	.....	1	.43 $\odot$ 1
14.287.....	.....	1	.....	1	Bl. of .19 $Fe$ and .43 $\odot$
14.572.....	14	1	24	3	.53 $Cr^?$
14.325.....	17	2	52	6	Bl. of .19 $Fe$ , .43 $\odot$ , .53 $Cr$
14.868.....	23	0	25	6	.....
15.337.....	5	4	40	7	.34 $Fe^+$ , $\odot$ 3, sp. 1; .18 $Fe$ Pred. and .44 $Cr$ indeterm.
15.782.....	14	—1	26	3	.....
16.090.....	28	—2	24	3	.....
16.427.....	20	—1	36	6	.....
16.704.....	.....	—1	24	1	.66 $\odot$ ( $Co^?$ ) 0, sp. —1
16.932.....	.....	—3	.....	1	.93 $\odot$ ? —2d?
17.116.....	10	0	20	2	.09 $\odot$ ( $Co$ ) —2; .16 $\odot$ 0, sp. 1
17.539.....	17	0	31	6	.53 $Fe$ , $\odot$ 3, sp. 3
18.054.....	21	1	23	2	.02 $Ti$ , $\odot$ 3, sp. 6
18.330.....	26	2	26	3	.34 $\odot$ 1, sp. 0
18.219.....	18	2	60	4	Bl. of 2 prec. lines
18.676.....	49	—1	.....	2	.59 $\odot$ ( $-Cr$ ) 0, sp. od; .70 $Ti$ , $\odot$ 0, sp. 2
19.168.....	11	0	.....	2	.....
19.493.....	19	0	22	3	.....
19.855.....	15	—1	.....	3	.85 $Cr^?$ , $\odot$ —1N; .99 $Ni^?$ , $\odot$ 0, sp. 0
20.222.....	7	4	41	7	.24 $Fe^+$ , $\odot$ 3, sp. 1; .36 $Ti^+$ not represented in meas.
20.584.....	.....	1	.....	1	.55 $V^+$ , $\odot$ —1N
20.814.....	.....	1	15	1	.81 $\odot$ —1N
20.973.....	12	—1	23	3	.....

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4521.178.....	27	1	20	2	.14 Cr, $\odot$ o, sp. o
21.350.....	3	0	23	2	
21.782.....	27	-1	23	3	
22.308.....		0	n	1	.37 La <sup>+</sup> , $\odot$ -1
22.648	8	5	43	7	.64 Fe <sup>+</sup> , $\odot$ 3, sp. 1; .80 Ti, $\odot$ 2, sp. 5; .53 Fe, $\odot$ o, sp. o, indetermin.
23.121.....		0	16	1	.09 $\odot$ (Ce <sup>+</sup> , Sa <sup>+</sup> ) o, sp. o
23.372.....	18	0	25	5	.40 Fe, $\odot$ 1, sp. 1
23.701.....	30	0	24	3	.59 $\odot$ ? -2N; .74 Ni, $\odot$ -2N
23.930.....	17	0	23	4	.92 Sa <sup>+</sup> , $\odot$ -1, sp. -2
24.088.....	3	-1	30	2	.10 Fe, $\odot$ -1
24.310.....	44	-2	25	2	.23 $\odot$ (V) -1, sp. o
24.714.....	20	0	29	6	.73 Ti <sup>+</sup> , $\odot$ o, sp. o
25.123.....	9	3	36	6	.95 Ba <sup>+</sup> , $\odot$ o, sp. -1; .15 Fe, $\odot$ 5, sp. 6
25.571.....		0	19	1	.62 $\odot$ ? -2N
25.808.....	26	0	26	4	.88 Fe, $\odot$ o, sp. 1; .62 $\odot$ ?
26.446.....	9	2	46	7	.41 $\odot$ 1; .47 Cr, $\odot$ 2; .57 Fe, $\odot$ 1, sp. 1
26.942.....	9	2	29	6	.94 Ca, $\odot$ 3, sp. .5
27.378.....	17	0	26	7	.31 Ti, $\odot$ 3, sp. 6; .35 Ce <sup>+</sup> ; .47 $\odot$ (Cr, Ti) o, sp. 1
27.065.....		1		1	Bl. of 2 prec. lines
27.796.....	24	-1	25	4	.80 Fe; Y?; $\odot$ o, sp. o
28.058.....	15	-1	20	4	
28.619.....	7	7	44	7	.62 Fe, $\odot$ 8, sp. 10; .48 Ce <sup>+</sup> and .55 V <sup>+</sup> in- determ.
29.136.....	63	0	17	2	
29.527	4	4	36	7	.49 Ti <sup>+</sup> , $\odot$ 1; .56 Fe, $\odot$ 1; .68 Fe, $\odot$ 1, sp. 1, indicated
29.931.....	22	0	26	3	.86 Cr?, $\odot$ o, sp. 1
30.250.....	31	-1	30	3	
30.699.....	9	2	30	6	.69 Cr, $\odot$ o, .76 Cr, $\odot$ 1; sp. 3
31.115.....	7	3	35	6	.99 Co, $\odot$ 2, sp. 2; .16 Fe, $\odot$ 5, sp. 8
30.984.....	15	4	76	2	Bl. of 2 prec. lines
31.633.....	23	0	28	5	.64 Fe, $\odot$ 2, sp. 2
32.293.....	34	-1	27	4	
32.682.....	10	-1	26	2	
33.153.....	11	3	50	7	.97 $\odot$ 1, sp. 1; .05 $\odot$ o, sp. o; .24 Ti, $\odot$ 4, sp. 8
33.554.....	22	0	24	2	
34.023	2	6	39	7	.97 Ti <sup>+</sup> , $\odot$ 6, sp. 4; .17 Fe <sup>+</sup> , $\odot$ 1, sp. o; Co indetermin.
34.430.....	21	0	20	2	.48 Mk, $\odot$ -2
34.798.....	9	2	32	6	.78 Ti, $\odot$ 4, sp. 7
35.148.....		1	n	1	.14 Cr, $\odot$ o, sp. 1
35.622.....	10	3	30	7	.57 Ti, $\odot$ 3, sp. 6; .72 Cr, $\odot$ 1
35.982.....	15	2	27	7	.92 Ti, $\odot$ 2, sp. 5; .05 Ti, $\odot$ 2, sp. 4
35.773.....	11	3	65	4	Bl. of 2 prec. lines

||||| R. wkr.

||||| The observed wave-length indicates relative intensities of 6 for Ti<sup>+</sup> and 2 for Fe<sup>+</sup>.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4536.506.....		0	21	1	.51 Cr, $\odot$ -1, sp. -1
36.908.....		0	27	1	
37.193.....		-2	n	1	.22 Ti, $\odot$ -1, sp. 0
37.402.....	7	-1	21	2	.43 $\odot$ -1, sp. ob
37.721.....	27	-1	20	3	.68 Fe, $\odot$ 0, sp. 0
38.122.....	10	-2	20	2	
38.783*****	16	1	30	5	.76 Fe, $\odot$ -1N, sp. -1d?; .84 Fe, $\odot$ 0
39.662.....	10	1	60	5	.59 $\odot$ -1, sp. ob; .76 Ce <sup>+</sup> ; .79 Cr, $\odot$ 0N, sp. 2
40.640.....	14	1	45	6	Bl. of 2 foll. lines
40.438.....		0		1	.41 Ti, $\odot$ -1, sp. od?; .50 Cr, $\odot$ 2, sp. 3
40.689.....		1		1	.72 Cr, $\odot$ 2, sp. 3
41.034.....		0	n	1	.07 Cr, $\odot$ 0, sp. 1
41.523.....	7	4	43	7	.52 Fe <sup>+</sup> , $\odot$ 2, sp. 1; .33 Fe <sup>+</sup> not indicated.
42.312.....	30	1	25	4	.24 Zr, $\odot$ 0N, sp. 0; .43 Fe and Mn?, $\odot$ 1N, sp. 0
42.681.....	23	1	29	3	.61 Nd <sup>+</sup> ?; .63 Cr, $\odot$ 0; .72 Fe, $\odot$ 0
42.537.....	23	1	75	4	Bl. of 2 prec. lines
42.837.....		0	20	1	.85 Cr <sup>+</sup> Pred.?, $\odot$ -3
43.372.....	18	-1	29	4	
44.009.....	17	2	35	5	.84 Co?, $\odot$ 0, sp. -1; .96 Sa <sup>+</sup> ?; .02 Ti <sup>+</sup> , $\odot$ 1, sp. 0
44.650.....	15	1	30	7	.62 Cr, $\odot$ 1; .69 Ti, $\odot$ 3; Cr <sup>+</sup> Pred. in- determ.
45.003.....	20	1	20	2	.96 Ce <sup>+</sup> , $\odot$ -1N
45.255.....		2	19	1	.15 Ti <sup>+</sup> , $\odot$ 1, sp. 0; .34 Cr, $\odot$ 0, sp. 2
45.172.....	8	2	41	6	Bl. of 2 prec. lines
45.600.....	2			2	
45.967.....	5	2	34	7	.96 Cr, $\odot$ 3, sp. 6
46.463.....	9	-1	22	3	
46.955.....	16	2	30	3	.94 Ni, $\odot$ 1, .03 Fe, $\odot$ 2; sp. 3
47.317.....	11	1	26	3	.23 Ni, $\odot$ 0, sp. 0; and ?
47.022.....	13	1	50	4	Bl. of 2 prec. lines
47.868.....	7	2	38	7	.85 Fe, $\odot$ 3, sp. 3
48.488.....	62	0		2	? and .58 Mn, $\odot$ -1
48.771.....	27	1		5	.77 Ti, $\odot$ 2, sp. 5
48.719.....	30	1		3	Bl. of 2 prec. lines
49.594.....	5	9	55	7	.48 Fe <sup>+</sup> , $\odot$ 2, sp. 0; .63 Ti <sup>+</sup> , $\odot$ 6d, sp. 4; .82 0, sp. -1
50.288.....	9	0	20	4	
50.794.....	9	2	35	5	.80 Fe, $\odot$ 2, sp. 1
51.456.....	28	0	23	4	
51.856.....	27	1	23	3	
52.127.....		0		1	.14 $\odot$ 0, sp. -1
52.431.....	10	2	46	6	.25 Ti <sup>+</sup> Pred., $\odot$ 0, sp. 0; .45 Ti, $\odot$ 2; .55 Fe, $\odot$ 1
53.092.....	10	-1	26	6	.08 V, $\odot$ -1; .16 Ni, $\odot$ 0, sp. -1

\*\*\*\*\* On B 467 measured d. at .51 and .87, indicating probable presence of .47 Mn and .60 Fe.

THE SPECTRUM OF  $\alpha$  CANIS MINORIS

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TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4553.514	67	-2	25	2	
54.035	4	4	38	7	.04 Ba <sup>+</sup> , $\odot$ 8, sp. 10; .96 Zr <sup>+</sup> indetermin.
54.505	20	0	18	2	.47 Fe, $\odot$ 1, sp. 2
54.971	7	2	34	7	.99 Cr <sup>+</sup> , $\odot$ 2, sp. 1; .84 Cr and .07 Ti indetermin.
55.500	20	1	26	5	.48 Ti, $\odot$ 3, sp. 6
55.984	6	5	48	7	.90 Fe <sup>+</sup> , $\odot$ 3, sp. 1; .13 Fe, $\odot$ 4, sp. 4
56.658	18	0	30	3	
56.964	14	0	20	3	.94 Fe, $\odot$ 0, sp. 1
57.342	20	0	50	6	.29 $\odot$ , oN, sp. -1
57.858	30	0		2	.86 Ti, $\odot$ -1
58.080	5	-1		2	.09 Ti, .11 Fe, $\odot$ 0, sp. 1
58.007	15	0	40	2	Bl. of 2 prec. lines
58.317	42	0		2	.23 $\odot$ -1, sp. 0b; .48 La <sup>+</sup> , $\odot$ -1
58.652	11	4	42	7	.66 Cr <sup>+</sup> , $\odot$ 3, sp. 1; .84 Cr <sup>+</sup> Pred. indetermin.
59.139	28	-1	n	2	
59.330	9	-1		2	
59.716	8	0	23	2	
60.045	24	-1		2	.93 $\odot$ (Ni Ti) 0, sp. 1; .11 Fe, $\odot$ 2, sp. 2
60.251	36	0		3	.27 Ce <sup>+</sup> , $\odot$ -1, sp. -2
60.142	81	0	56	2	Bl. of 2 prec. lines
61.468	25	-1	40	3	.42 $\odot$ 1, sp. -1
62.314	21	0	30	4	.34 Ce <sup>+</sup> , $\odot$ 0, sp. -2
63.177	26	-1	28	3	
63.504		0	n	1	.43 Ti?, $\odot$ -1, sp. 1
63.767	4	4	39	7	.76 Ti <sup>+</sup> , $\odot$ 4, sp. 3
64.273	17	0	22	3	.23 Ti?, .34 $\odot$ ? -1
64.621	17	1	31	6	.56 Ni <sup>+</sup> ; .59 V <sup>+</sup> , $\odot$ -1, sp. -3; .72 Fe, $\odot$ 0, sp. -1
65.231	34	1	27	5	.17 Ni, $\odot$ -1N; .32 Fe, $\odot$ 0, sp. 0
65.646	10	2	35	5	.51 Cr, $\odot$ 3, sp. 5; .68 Fe, $\odot$ 2, sp. 1
65.597	8	2	62	3	Bl. of 2 prec. lines; .45 Ni indetermin.
66.136	43	0	24	3	.21 Sa <sup>+</sup> ?
66.578	22	1	29	3	.52 Fe, $\odot$ 1, sp. 2; .66 Fe Pred.?, $\odot$ -3
66.938	26	1	24	3	.88 Fe, $\odot$ 1, sp. 0; .99 Fe, $\odot$ -1, sp. 0
66.785	21	1	60	4	Bl. of 2 prec. lines
67.494	51	1	25	2	.41 Ni?, $\odot$ -1N
68.345	17	1	32	5	.31 Ti <sup>+</sup> , $\odot$ 0, sp. -1
68.833	26	1	33	4	.79 Fe, $\odot$ 1, sp. 0; .84 Fe, $\odot$ 0, sp. 1
69.542	24	-1	36	4	.30 Co <sup>+</sup> ?, .54 Cr -1; .63 Cr, $\odot$ 0
70.060	53	-1	31	3	.02 Co?, $\odot$ -1N
70.517	30	-2	35	5	
71.120	4	2	42	6	.11 Mg, $\odot$ 5, sp. 8; .91 Ti and .30 Cr <sup>+</sup> Pred. present?
71.591	31	0	20	2	.45 Fe Pred.?, $\odot$ 0, sp. 0; .68 Cr, $\odot$ 1, sp. 2
71.984	6	5	45	7	.97 Ti <sup>+</sup> , $\odot$ 6, sp. 4
72.341		1		1	.28 Ce <sup>+</sup> , $\odot$ -1
72.620		1	28	1	.60 $\odot$ -1, sp. 0
72.863	18	0	33	3	.87 $\odot$ (Fe? Cr <sup>+</sup> Pred.) 0, sp. -1

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4573.424.....	$\pm$ 2	0	22	2	.....
73.914.....	20	-1	.....	2	.00 Ni?
74.220.....	21	0	37	6	.24 Fe, $\odot$ 1, sp. 1
74.787.....	23	1	46	5	.73 Fe, $\odot$ 2, sp. 3; .90 La <sup>+</sup> , $\odot$ -1d?
75.254.....	10	0	24	3	.....
75.680.....	18	-1	27	5	.....
76.338.....	7	3	40	7	.34 $\odot$ (Fe <sup>+</sup> ) 2, sp. 0
76.812.....	23	-1	23	4	.70 $\odot$ (Cr <sup>2</sup> ) -2
77.216.....	38	0	30	5	.18 V?, $\odot$ 0, sp. 5
77.711.....	28	-1	40	4	.71 Sa <sup>+</sup> , $\odot$ -1
78.072.....	48	0	21	2	.05 Fe, $\odot$ -1Nd?, sp. -1N
78.526.....	5	3	47	6	.33 Cr, $\odot$ -1; .57 Ca, $\odot$ 3, sp. 7; .74 V?
79.092.....	45	1	22	2	.....
79.464.....	2	-1	20	2	.....
79.308.....	24	1	45	3	Bl. of 2 prec. lines; includes .34 Fe
80.030.....	9	2	49	7	.83 Fe, $\odot$ 0, sp. -1; .06 $\odot$ (Cr, La <sup>+</sup> ) 3, sp. 6
80.533.....	36	1	37	5	.40 V, $\odot$ 1, sp. 1; .47 Ti <sup>+</sup> ; .60 Fe, .61 Ni, $\odot$ 1, sp. 0
81.445.....	7	4	44	7	.20 $\odot$ 0, sp. -1; .45 Ca, $\odot$ 4; .52 Fe, $\odot$ 4
82.165.....	25	0	28	5	.18 I?
82.805.....	9	2	36	7	.84 Fe <sup>+</sup> , $\odot$ 1, sp. -1
83.306.....	20	0	23	7	? and .44 Ti <sup>+</sup> , $\odot$ 0, sp. 1
83.865.....	7	5	36	7	.84 Fe <sup>+</sup> , $\odot$ 4, sp. 2; .85 Cr indetermin.
84.814.....	13	2	31	6	.73 Fe, $\odot$ 1; .83 Fe, $\odot$ 2; .84 Sa <sup>+</sup> ?
85.346.....	4	0	20	3	.35 $\odot$ 0, sp. -1
85.873.....	12	3	32	5	.87 Ca, $\odot$ 4, sp. 8; .98 $\odot$ 0, sp. 0; .82 Al <sup>+</sup> indetermin.
86.153.....	15	2	30	4	.14 Cr?
86.320.....	6	-1	30	2	.24 $\odot$ 1, sp. 0; .37 V, $\odot$ 1, sp. 4
87.112.....	18	1	41	5	.14 Fe, $\odot$ 2, sp. 1
87.728.....	22	-1	21	3	.....
88.199.....	10	3	43	7	.21 Cr <sup>+</sup> , $\odot$ 3, sp. 1; .4 Cr <sup>+</sup> Pred. not in- dicated
88.742.....	22	-2	23	3	.....
89.063.....	38	-2	34	3	.....
89.384.....	18	0	25	2	.....
89.596.....	41	0	15	2	.....
89.951.....	5	3	42	7	.95 Cr <sup>+</sup> ; .96 Ti <sup>+</sup> , $\odot$ 3, sp. 2
90.629.....	30	-1	25	5	.....
90.981.....	12	-1	25	4	.....
91.442.....	16	2	35	6	.41 Cr, $\odot$ 2, sp. 4; .52 $\odot$ 1, sp. 0
92.054.....	17	2	31	6	.06 Cr <sup>+</sup> , $\odot$ 1, sp. 0
92.639.....	13	3	38	6	.53 Ni, $\odot$ 2, sp. 2; .66 Fe, $\odot$ 4, sp. 6
93.406.....	20	0	36	5	Bl. of 2 foll. lines
93.274.....	.....	.....	.....	1	.18 $\odot$ -1, sp. 0; .37 $\odot$ -2
93.580.....	.....	.....	.....	1	.54 $\odot$ (Fe) 1, sp. 1
93.966.....	10	1	42	4	.83 Cr, $\odot$ -1, sp. -1; .93 Ce <sup>+</sup> , $\odot$ 0; .10 V, $\odot$ 2N, sp. 6

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4593.757		1	81	1	Bl. of 3 prec. lines
94.921	33	0	26	2	.89 Ni, $\odot$ o, sp. -1
95.376	17	2	40	6	.30 Sa <sup>+</sup> ?; .37 Fe, $\odot$ 2, sp. 3
96.028	17	2	43	6	.93 Ni, $\odot$ o, sp. 1; .06 Fe, $\odot$ 2, sp. 3
96.486	34	0	23	2	.42 $\odot$ (Fe) 1, sp. 1
97.157	10	1	48	4	.91 Co, $\odot$ o, sp. o; .06 Fe Pred., $\odot$ -1, sp. o; .26 $\odot$ o; .30 $\odot$ o, sp. -1
97.795				1	.76 $\odot$ 1, sp. 1; .88 $\odot$ 1, sp. 1
98.113				1	.13 Fe, $\odot$ 3, sp. 4
97.992	8	3	64	6	Bl. of 2 prec. lines
98.519	48	-1		2	
98.840	13	-1	35	2	.74 Fe, $\odot$ o, sp. od; .94 Mn?, $\odot$ -2; .99 Ti, $\odot$ -1, sp. -1
99.274	18	-1	22	3	.23 Ti, $\odot$ -1, sp. 1
99.843	16	2	51	6	.84 $\odot$ (Fe?) 2, sp. 2
4600.306	16	2	20	5	.22 V <sup>+</sup> , $\odot$ -1N; .36 Ni, $\odot$ 2, sp. 2
00.790	15	2	45	5	.75 Cr, $\odot$ 3, sp. 7; .94 Fe, $\odot$ o; .02 Cr, $\odot$ o
00.400	15	2	137	2	Meas. of 3 prec. lines
01.359	25	1	24	3	.38 Fe <sup>+</sup> , $\odot$ -1, sp. ob
01.994	11	2	34	5	.01 Fe, $\odot$ 3, sp. 4
02.942	3	4	42	7	.95 Fe, $\odot$ 6, sp. 8
03.482	59	0	26	2	
03.814	32	0	38	5	.63 $\odot$ -1; .73 $\odot$ (Cs <sup>+</sup> ) -1, .86 $\odot$ o; .96 Fe, $\odot$ o, sp. 1
04.168	23	0	n	2	.17 Sa?
04.529	12	1	26	3	? and .60 Fe, $\odot$ 2, sp. 1
04.997	10	1	38	6	.99 Ni, $\odot$ 3, sp. 3
05.508	12	0	29	4	.37 Mn, $\odot$ o, sp. o; .60 $\odot$ 2, sp. 2
05.746		1	26	1	.79 La <sup>+</sup>
06.262	19	1	38	5	.22 Ni, $\odot$ 2, sp. 4; .41 Ce <sup>+</sup>
07.208	34	0	30	4	
07.645	18	2	31	6	.66 Fe, $\odot$ 4, sp. 4
07.994		0	n	1	.98 V <sup>+</sup>
08.305		-1	n	1	.20 Ni?
08.763	32	0	24	4	
09.266	38	0	30	4	.27 Ti <sup>+</sup> , $\odot$ o, sp. ob
10.219		0	35	1	.19 $\odot$ o, sp. o
11.272	17	3	42	6	.19 Fe Pred., $\odot$ o, sp. o; .29 Fe, $\odot$ 5, sp. 7
11.827	1	1	n	2	
12.031	24	-1	24	2	.96 Cr, $\odot$ -1, sp. o
12.327		1		1	.27 Dy <sup>+</sup> ?, $\odot$ -2
12.660	27	0	28	6	
13.278	18	3	42	6	.21 Fe, $\odot$ 3, sp. 4; .37 Cr; .40 La <sup>+</sup> , $\odot$ 3, sp. 5
13.902	20	1	26	6	.93 Zr <sup>+</sup> , $\odot$ 1, sp. 1; and ?
14.577	44	0	32	3	
14.979	24	-1	40	2	
15.595	3	0	28	4	.57 Fe, $\odot$ 1, sp. o; .45 Sa <sup>+</sup> and .70 Sa <sup>+</sup> in- determ.

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
	$\pm$				
4616.140.....	12	2	35	6	.13 Cr, $\odot$ 4, sp. 8; .23 $Ti^+$ prob. present.
16.660.....	9	2	33	6	.63 $Cr^+$ , $\odot$ 1N, sp. 0
17.261.....	17	1	27	5	.27 Ti, $\odot$ 3, sp. 5
17.737.....	33	0	20	2	
17.403.....		1	67	1	Bl. of 2 prec. lines
17.934.....	10	0	30	2	.87 $\odot$ -1; .98 $\odot$ -1
18.197.....	30	0	32	3	
18.804.....	14	4	37	6	.76 Fe; .82 $Cr^+$ , $\odot$ 4d <sup>2</sup> , sp. 3
19.295.....	11	2	25	2	.30 Fe, $\odot$ 3, sp. 3; measure of Fe alone
19.398.....	7	2	39	4	Bl. of .30 Fe and .54 Cr
19.878.....	25	-1	30	3	.86 $La^+$ , $\odot$ -3
20.138.....	59	1		2	
20.500.....	9	3	38	7	.52 $Fe^+$ , $\odot$ 2, sp. 0
20.974.....	33	-1	33	2	
21.280.....	28	0	20	3	
21.753.....	24	1	44	5	.70 Ca?; .89 Cr?
22.266.....	7	1	38	2	
22.498.....	7	0	38	3	.49 Cr, $\odot$ 1, sp. 2
22.750.....		-1		1	.76 Cr, $\odot$ 0, sp. 1
23.108.....	18	0	35	4	.10 Ti, $\odot$ 2, sp. 4
23.487.....		-1	n	1	.59 $\odot$ ? 0
23.799.....	20	0	48	2	Bl. of .59 $\odot$ 0 and .88 $\odot$ -2N?
24.515.....		-1		1	.42 $V^+$ , $\odot$ -1, sp. 1; .57 $Cr^+$ , $\odot$ -1N
25.048.....	13	2	35	7	.06 Fe, $\odot$ 5, sp. 6; .90 $Ce^+$ present.
25.563.....	27	-1	24	3	.44 Fe Pred. and ?
25.874.....				1	.92 Cr, $\odot$ 0N, sp. 1
26.154.....	14	2	40	6	.18 Cr, $\odot$ 5, sp. 6
26.568.....	7	0	23	2	.54 Mn, $\odot$ 0, sp. 1
27.186.....	14	0	40	3	.2 Eu?
27.591.....	3	0	34	2	.55 $\odot$ 0
28.231.....	4	-1	36	2	.15 $Ce^+$ , $\odot$ 0, sp. 0
28.653.....	9	0	23	3	.69 $\odot$ (Fe) -1
29.075.....		1	15	1	.06 $Zr^+$ , $\odot$ -1
29.340.....	6	5	37	7	.33 $Fe^+$ , $\odot$ 6, sp. 7; .34 Ti and .38 Co in- determ.
29.838.....		1	18	1	.81 Zn?, $\odot$ -1
30.115.....	20	2	35	5	.13 Fe, $\odot$ 4, sp. 4
30.722.....	22	1	30	2	.57 $\odot$ 0, sp. -2; .78 Fe, $\odot$ -1N
31.419.....		-1	29	1	.49 Fe, $\odot$ 0, sp. -1
31.955.....	49	1	36	3	Prob. present: .73 $\odot$ -1d?; .96 $\odot$ -1d?; .15 Cr, $\odot$ 0, sp. -1
32.404.....	31	0		2	
32.911.....	14	3	38	6	.82 Fe, $\odot$ 1, sp. 1; .92 Fe, $\odot$ 4, sp. 6
33.697.....	20	0	27	4	? and .78 Fe Pred.
34.083.....	8	3	38	5	.11 $Cr^+$ , $\odot$ 2, sp. 0
34.011.....	18	3	63	2	Bl. of 2 prec. lines
34.551.....	6	-1	26	3	
35.316.....	56	0	24	2	.32 $Fe^+$ , $\odot$ 0, sp. 0b
35.845.....	25	0	40	3	.85 Fe, $\odot$ 2, sp. 2

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4636.505	$\pm 42$	0	29	3	.35 <i>Ti</i> , $\odot$ 0, sp. -1; .50 <i>La</i> <sup>+</sup>
37.494	11	2	30	4	.52 <i>Fe</i> , $\odot$ 5, sp. 6
37.982	10	3	32	4	.02 <i>Fe</i> , $\odot$ 4, sp. 3
37.783	26	3	106	2	Bl. of 2 prec. lines
38.686		0	43	1	Bl. of .54 $\odot$ -1, .71 <i>Nd</i> <sup>+</sup> , $\odot$ -1N, and .96 $\odot$ 0?
39.358		-1	39	1	.37 <i>Ti</i> , $\odot$ 2, sp. 5
39.804		-1	37	1	.67 <i>Ti</i> , $\odot$ 2, sp. 4; .94 <i>Ti</i> , $\odot$ 1, sp. 4
40.263		-1	37	1	.29 $\odot$ ( <i>Fe</i> ?) 1, sp. 0
41.302	84	0	35	2	.22 $\odot$ 0, sp. -2 and ?
41.960		-1	37	1	.01 <i>Cr</i> , $\odot$ -1
42.337		0		1	.24 <i>Sa</i> <sup>+</sup> , $\odot$ -1
42.698		-1		1	.59 <i>Fe</i> Pred., $\odot$ -1N; .83 $\odot$ -1
43.462	11	2	40	4	.47 <i>Fe</i> , $\odot$ 4, sp. 3
44.449		-1	25	1	
45.259		1	37	1	.19 <i>Ti</i> ? $\odot$ 0, sp. 3; .32 <i>La</i> <sup>+</sup> , $\odot$ -2
45.754		-1	28	1	.77 <i>Nd</i> <sup>+</sup> ?, $\odot$ -1
46.166	17	3	31	6	.17 <i>Cr</i> , $\odot$ 5, sp. 8
46.720	28	-1	24	3	.64 $\odot$ 1, sp. 2; .80 <i>Cr</i> , $\odot$ 0, sp. 1
47.424	11	2	34	6	.28 $\odot$ 0, sp. -1; .44 <i>Fe</i> , $\odot$ 4, sp. 6
47.902	27	1		2	.96 $\odot$ 1, sp. 0
48.135		1	31	1	.13 <i>Cr</i> , $\odot$ 0, sp. 1
48.318		0	38	1	.32 <i>Fe</i> <sup>+</sup> , $\odot$ -2
48.715	19	2	37	5	.66 <i>Ni</i> , $\odot$ 4, sp. 3; .86 <i>Cr</i> ?, $\odot$ -1, sp. 1
49.566	35	1	26	3	.44 <i>Cr</i> , $\odot$ 0, sp. 1; .65 $\odot$ 0 <i>Nd</i> ?
50.155		0	37	1	.02 <i>Ti</i> , $\odot$ 0, sp. 2; .32 $\odot$ 0
50.461		1		1	
51.282	24	2	38	5	.30 <i>Cr</i> , $\odot$ 4, sp. 7
52.147	10	2	57	5	.17 <i>Cr</i> , $\odot$ 5, sp. 9
53.054	58	0	29	2	
53.405	62	0	35	2	.38 $\odot$ ( <i>Ti</i> ?) -1; .49 <i>Fe</i> Pred., $\odot$ -1
54.561	10	5	47	6	.50 <i>Fe</i> , $\odot$ 4, sp. 5; .64 <i>Fe</i> , $\odot$ 5, sp. 6
55.482	5	0	25	2	.49 <i>La</i> <sup>+</sup> , $\odot$ -2d?
55.724	55	1	45	3	.69 <i>Ni</i> ?, $\odot$ 0; .80 <i>Ti</i> ?, $\odot$ 0, sp. 1
56.040		-2	n	1	.05 <i>Ti</i> , $\odot$ 0, sp. 1
56.450	21	0	40	4	.47 <i>Ti</i> , $\odot$ 3 sp. 6
57.060	16	2	41	3	.98 <i>Fe</i> <sup>+</sup> , $\odot$ 1, sp. 0; .18 <i>Ti</i> <sup>+</sup> , $\odot$ 2, sp. 1
57.496	50	1	32	2	.4 <i>Co</i> , <i>Mn</i> ?, $\odot$ -1; .60 <i>Fe</i> , $\odot$ 1, sp. 2
57.134	0	3		2	Bl. of 2 prec. lines
58.338	66	0	30	2	.30 $\odot$ ( <i>Y</i> ) 0, sp. 1
58.877		-1	n	1	.88 $\odot$ ( <i>Y</i> ?) -1d?, sp. 0
60.745		-2	30	1	.91 $\odot$ 0, sp. 0
61.380		-2	40	1	.54 <i>Fe</i> , $\odot$ 1, sp. 0
61.989	8	0	32	2	.98 <i>Fe</i> , $\odot$ 1, sp. 2
63.404	11	1	27	2	.32 <i>Cr</i> , $\odot$ 1, sp. 2; .42 $\odot$ ( <i>Co</i> ) 0
63.870	45	1	26	2	.85 <i>Cr</i> , $\odot$ 1, sp. 2; .97 $\odot$ 0, sp. 1
63.609	22	3	63	2	Bl. of 2 prec. lines and .71 <i>Fe</i> <sup>+</sup> , $\odot$ 0, sp. ob
64.841	42	2	47	3	.81 <i>Cr</i> , $\odot$ 3, sp. 5
65.963	25	1	40	4	.92 <i>Cr</i> , $\odot$ 1, sp. 1; .11 $\odot$ 0, sp. 0

TABLE IV—Continued

$\alpha$ CANIS MINORIS					LABORATORY AND SUN
Observed $\lambda$	P.E. (.001 Å)	Inten.	Width (.01 Å)	No. of Plates	
4666.717.....	$\pm 12$	2	44	4	.61 $\odot$ 0, sp. 0; .75 $Fe^+$ , $\odot$ 1, sp. 0
67.500.....	14	3	45	5	.46 $Fe$ , $\odot$ 4, sp. 3; .59 $Ti$ , $\odot$ 3, sp. 6
68.125.....	11	2	33	4	.07 $\odot$ 2; .15 $Fe$ , $\odot$ 4
68.611.....	41	0	31	3	.57 $\odot$ 1N, sp. 3
69.232.....	14	1	37	5	.18 $Fe$ , $\odot$ 3, sp. 2; .36 $Cr$ , $\odot$ 1, sp. 2; .39 $Sa^+$ , $\odot$ -2
69.663.....		0		1	.66 $\odot$ ( $Sa^+ - Cr?$ ) -1, sp. 0
70.342.....	14	4	50	5	.18 $\odot$ 1, sp. -1; .40 $Sc^+$ , $\odot$ 2, sp. 2; .56 $Nd^+$ , $\odot$ -1
71.004.....				1	
71.636.....	50			2	.42 $\odot$ 1, sp. 0; .69 $Mn$ , $\odot$ 0, sp. 0
71.296.....		1	60	1	Bl. of 2 prec. lines
71.982.....		1	29	1	.04 $\odot$ ? -1
72.380.....		2	31	1	.34 $\odot$ 3N, sp. 2
72.269.....	29	2	71	4	Bl. of 2 prec. lines
72.778.....		-1	20	1	.84 $Fe$ Pred., $\odot$ 1, sp. 2
73.192.....	23	2	63	3	.17 $Fe$ , $\odot$ 4, sp. 4; .28 $Fe$ , $\odot$ 1, sp. 1
74.160.....		1	31	1	.10 $\odot$ 1N, sp. 0; .3 $Fe$ , $\odot$ 0, sp. 1
74.668.....		1	34	1	Bl. ? of .60 $Sa^+$ , .65 $Fe$ Pred., and .76 $\odot$
75.315.....		1	41	1	.12 $Ti$ , $\odot$ 1N, sp. 4, and ?
75.584.....		1	35	1	.61 $\odot$ ( $Ni?$ ) 0, sp. -1
77.056.....	35	0	47	2	.91 $Sa^+$ and .09 $\odot$ ? -1
78.176.....	37	2	36	3	.18 $\odot$ 3N, sp. 2
78.917.....	23	3	42	3	.86 $Fe$ , $\odot$ 6, sp. 6
79.414.....		1	23	1	.23 $Fe$ , $\odot$ 2N, sp. 1
80.186.....	4	3	38	2	.14 $\odot$ ( $Zn$ , $Ce^+$ ) 1, sp. -2; .30 $Fe$ , $\odot$ 1, sp. 2
80.792.....	30	2	45	2	.74 $Nd^+$ , $\odot$ -1; .86 $Cr$ , $\odot$ 0, sp. 1
80.306.....		4	92	1	Bl. of 2 prec. lines, incl. 48 $Fe$ and .57 $\odot$
81.409.....		1	42	1	.46 $Fe$ , $\odot$ 1, sp. 0
82.065.....	19	3	74	2	.91 $Ti$ , $\odot$ 3, sp. 7; .11 $Fe$ , $\odot$ 1, sp. 0; .33 $Y^+$ , $\odot$ 1, sp. 0
83.104.....	2	1	39	2	
83.641.....		1	39	1	.57 $Fe$ , $\odot$ 3, sp. 3
91.613.....		2	31	1	.42 $Fe$ , $\odot$ 5; .60 $\odot$ 1N, sp. 0
4702.971.....		4	52	1	.07 $Mg$ , $\odot$ 10, sp. 9

The probable errors in column 2 of Table IV were computed by the second-power formula from the differences of the individual observations from the means given in column 1. A large probable error indicates that, although the absorption is real, the measures are uncertain because of the inferior quality of the line. A high probable error, confined almost exclusively to lines of low intensity, results from the formation of the mean from measures spreading over a

fairly large range in wave-length, caused by the fortuitous exclusion of a component in the measures of one plate and its inclusion in measures of other plates. The probable error is a sufficiently reliable indication of the range covered. On a sharply defined line individual settings with the micrometer will duplicate each other repeatedly to within 0.01 Å. For the 53 normal lines listed in Table I, the computed probable error is in no case greater than  $\pm 0.011$  Å and the average value is  $\pm 0.0059$  Å. For these lines the average actual deviation of the observed from the normal wave-length is  $\pm 0.0076$  Å. For an observed wave-length determined from only two plates, seven-tenths of one-half the range is given as its probable error. This device for indicating the range between two observations is of value in assigning identifications.

The observed stellar wave-lengths in Table IV were considered quite satisfactory since they show only reasonably moderate deviations of apparently purely accidental nature from the corresponding laboratory and solar wave-lengths. However, the inherent accuracy of the measures is slightly greater than would be inferred from the residuals alone. Personality in the measurement of close pairs is shown in a few cases in a tendency for the components of the pair to be displaced away from each other. The displacement of each component of such a pair, as determined from these measures for lines of known origin and position in laboratory spectra, seems to be approximately 0.004 mm at separation 0.15 Å (at  $\lambda$  4500), 0.003 mm at separation 0.20 Å, 0.002 mm at separation 0.24 Å, and vanishes at 0.31 Å separation. No corrections for personality have been applied, because the exact relation of the effect to actual and relative intensities of components is not yet known with sufficient accuracy. The lines which were employed as normals are free from personality, and only about 10 per cent of all lines may contain small personality shifts. The data in Table IV will at some future time be combined with other similar data for the determination of definitive corrections for personality. Such corrections are unnecessary for most purposes, but should be applied before a refined discussion of displacements of individual lines in the stellar spectrum is attempted. In discussions of large groups of lines involving positions but not separations, the lines containing personality shifts will constitute only a small per-

TABLE V

ELEMENT	AVERAGE OBSERVED INTENSITY	NUMBER OF LINES	NUMBER OF MEASURES	DIFFERENCES IN WAVE-LENGTH			
				Procyon—Laboratory		Sun—Laboratory	
				Neutral	Ionized	Neutral	Ionized
<i>Fe</i> .....	2.1	120	492	-.0026 Å	.....	+.0020 Å	.....
<i>Fe</i> <sup>+</sup> .....	3.5	21	105	.....	-.0043 Å	.....	-.0001 Å
<i>Ti</i> .....	0.6	31	90	+.0088	.....	+.0077	.....
<i>Ti</i> <sup>+</sup> .....	2.9	41	204	.....	+.0015	.....	+.0035
<i>Cr</i> .....	1.4	37	114	+.0059	.....	-.0003	.....
<i>Cr</i> <sup>+</sup> .....	2.5	11	53	.....	-.0028	.....	-.0014
<i>La</i> <sup>+</sup> .....	-0.3	11	24	.....	+.0014	.....	+.0010
<i>Ce</i> <sup>+</sup> .....	0.4	10	25	.....	+.0026	.....	+.0052
<i>Sa</i> <sup>+</sup> .....	-0.5	10	26	.....	+.0021	.....	-.0012
<i>Mn</i> .....	1.0	13	42	-.0090	.....	+.0036	.....
<i>Sc</i> <sup>+</sup> .....	3.0	9	45	.....	-.0089	.....	+.0037
<i>Ca</i> .....	3.0	13	77	+.0026	.....	+.0077	.....
<i>Ni</i> .....	0.9	18	66	+.0077	.....	+.0045	.....
<i>V</i> .....	-0.1	15	42	+.0035	.....	+.0005	.....
Means for all lines.....		360	1405	+.0012 Å	-.0007 Å	+.0028 Å	+.0020 Å
<i>Fe, Ti, Cr</i> .....		261	1058	+.0010	-.0008	+.0025	+.0018

TABLE VI

DIFFERENCES IN WAVE-LENGTH, PROCYON—LABORATORY;  
NUMBER OF LINES; NUMBER OF MEASURES

Intensity Element	8 to 5	4 to 3	2 to 1	0 to -2
<i>Fe</i> .....	-.0011 Å; 9; 45	-.0056 Å; 23; 127	-.0040 Å; 49; 203	+.0023 Å; 31; 101
<i>Ti</i> .....	.....	.....	+.0114 ; 15; 55	+.0046 ; 15; 35
<i>Cr</i> .....	.0000 ; 1; 1	+.0107 ; 3; 18	+.0022 ; 17; 59	+.0135 ; 15; 35
<i>Mn</i> .....	.....	.....	-.0101 ; 5; 19	-.0124 ; 6; 17
<i>Ca</i> .....	.....	-.0008 ; 9; 56	+.0118 ; 4; 21	.....
<i>Ni</i> .....	.....	.....	+.0085 ; 12; 47	+.0075 ; 6; 19
<i>V</i> .....	.....	.....	+.0252 ; 2; 4	+.0039 ; 13; 38
Means.....	-.0011 Å; 10; 46	-.0029 Å; 35; 201	+.0012 Å; 104; 408	+.0037 Å; 86; 245
<i>Fe</i> <sup>+</sup> .....	+.0150 Å; 3; 21	-.0031 Å; 11; 69	-.0275 Å; 4; 15	-.0033 Å; 2; 3
<i>Ti</i> <sup>+</sup> .....	+.0033 ; 7; 43	-.0029 ; 10; 51	+.0042 ; 20; 96	-.0030 ; 3; 12
<i>Cr</i> <sup>+</sup> .....	.....	-.0140 ; 5; 26	+.0003 ; 4; 21	+.0345 ; 2; 6
<i>La</i> <sup>+</sup> .....	.....	.....	-.0420 ; 3; 3	+.0076 ; 8; 21
<i>Sc</i> <sup>+</sup> .....	-.0155 ; 2; 4	-.0099 ; 4; 22	-.0063 ; 3; 19	.....
Means.....	+.0058 Å; 12; 68	-.0056 Å; 30; 168	-.0016 Å; 34; 154	+.0076 Å; 15; 42

centage of the total number of lines considered, the positive and negative displacements will approximately balance each other, and the probable error of the result will be slightly increased, but no appreciable systematic effect will enter.

The observed wave-lengths in Table IV were studied for the detection of possible systematic displacements in the wave-lengths of the different elements. The principal results are summarized in Table V. Only those lines were used which are essentially free from companions of sufficient proximity or strength to influence the measured positions. The elements are represented quite unequally in number and in average intensity. *Fe* constitutes one-third of all lines included in Table V as well as in the entire list of identified lines. On the whole, the evidence is negative for systematic displacements of the lines of one element relative to the lines of other elements, or of the lines of the neutral atoms relative to those of the ionized atoms. Similarly, the residuals, separated according to the observed line intensities, as in Table VI, give no evidence of a relation between displacements (residuals) and line intensities for either the arc or the enhanced lines.

CARNEGIE INSTITUTION OF WASHINGTON  
DUDLEY OBSERVATORY, ALBANY, N.Y.  
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## THE ORBIT OF BOSS 35 BR.\*

By ELIZABETH MACCORMACK

### ABSTRACT

A determination of the orbit of the brighter component of Boss 35 from fifty-five spectrograms obtained at the Mount Wilson Observatory.

The visual double star  $\Sigma_{12}$  (Boss 35)<sup>1</sup> with components of magnitude 5.9 and 7.5, separated by  $11''.53$  in p.a.  $149^\circ$ , has shown no relative motion in an interval of forty years. Both components have been observed for radial velocity.

A variable velocity for the bright component was apparent from the measures of the first three plates, two of which showed double lines—a fact not previously announced. Fifty spectrograms were ob-

TABLE I

#### PRELIMINARY ELEMENTS

$P = 0.84166$ days	$K_1 = 86.2$ km/sec.
$T = \text{J.D. } 2426974.242$	$K_2 = 91.0$
$e = 0.05$	$\gamma = +2.3$
$\omega_1 = 144.7$	
$\omega_2 = 324.7$	

tained between October, 1931, and July, 1933. Five other plates obtained before 1931 were not used in computing the orbit but were useful in determining the period. Table II contains the data for the fifty-five spectrograms, all of which were taken at the 60-inch telescope. Twenty-nine of the fifty plates used gave velocities for both components. No significant difference could be noted in the strength of the lines of the two members of the system or in the spectral type, which is A9s. It was found that a period of 0.841657 days gave a satisfactory assemblage of all the observations around a single epoch and furnished a smooth velocity-curve from which the preliminary elements in Table I were computed by Russell's method.<sup>2</sup>

\* *Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington*, No. 495.

<sup>1</sup> 35 Piscium, HD 1061,  $\beta$ GC 87, BD  $+8^\circ 19$ ; 1900,  $\alpha = 0^h 9^m 8$ ,  $\delta = +8^\circ 16'$ .

<sup>2</sup> *Ap. J.*, **40**, 282, 1914.

TABLE II  
MOUNT WILSON RADIAL VELOCITIES OF BOSS 35 BR.

PLATE No.*	DATE	G.M.T.	PHASE	VELOCITY		RESIDUALS	
				Prim.	Second.	Prim.	Second.
			days	km/sec.		km/sec.	
$\gamma$ 13865...	1925 Oct. 29	18 <sup>h</sup> 46 <sup>m</sup>	0.349		- 1.8		
13876...	Nov. 5	18 08	.590	+94.5	-98.7	+ 8	-13
13877...	5	18 53	.621	+88.0	-89.1	+ 8	- 9
13971...	1926 Jan. 4	15 06	.706		+14.0		
17799...	1930 Oct. 6	22 25	.673	+71.9	-85.4	+11	-25
18497...	1931 19	19 55	.665	+84.7	-65.0	+21	- 1
18508...	22	15 45	.125	-82.2	+95.2	+ 7	- 3
18512...	22	21 44	.375		- 9.3		
V 63...	24	21 44	.601		+ 2.4		
$\gamma$ 18517...	25	15 48	.602	+88.0	-94.0	+ 4	-10
18523...	26	15 51	.762		+ 7.8		
18525...	26	19 50	.086	-72.5	+96.6	+11	+ 5
V 86...	30	19 05	.680	+47.8	-69.0	- 5	-18
$\gamma$ 18556...	Nov. 18	17 08	.250	-79.0	+62.0	-21	- 4
18561...	19	15 01	.320		- 3.6		
18568...	20	18 58	.642	+76.6	-78.8	+ 3	- 5
18619...	Dec. 29	16 00	.803		- 2.2		
18642...	1932 Jan. 17	14 52	.398		+13.8		
18656...	19	15 16	.731		+13.8		
18675...	25	15 30	.007		-17.0		
18919...	June 24	22 48	.655	+81.8	-74.7	+13	- 7
18976...	Aug. 10	23 08	.536	+87.4	-78.0	+ 3	+ 6
18987...	12	22 53	.000		-21.2		
19053...	24	23 17	.234	-61.9	+93.4	+ 4	+19
19054...	24	23 56	.261		-26.4		
19055...	25	0 30	.285		-21.1		
19060...	Sept. 8	19 20	.768		-16.4		
19072...	9	22 09	.195	-76.1	+96.3	+ 4	+ 7
19083...	11	19 34	.404		+13.2		
19102...	12	19 50	.573	+83.4	-72.6	- 4	+13
19156...	22	21 02	.524	+78.1	-85.1	- 4	- 3
19157...	22	22 10	.572	+92.7	-77.8	+ 6	+ 8
19158...	22	22 42	.594	+80.4	-91.0	- 5	- 6
19162...	23	18 55	.594	+96.9	-95.7	+12	-11
19163...	23	19 17	.609	+91.1	-82.0	+ 8	+ 1
19166...	23	22 27	.741		+ 5.9		
19167...	23	22 46	.755		+ 3.8		
19178...	Oct. 10	18 08	.729		- 3.2		
19182...	10	21 21	.021	-66.2	+46.0	-10	-18
19211...	15	16 52	.626	+77.6	-98.7	- 1	-20
19215...	15	20 18	.769		- 5.0		
19216...	15	20 37	.782		- 3.8		
19225...	16	19 30	.052	-63.4	+89.0	+ 8	+ 9
19226...	16	19 55	.070	-82.0	+80.4	- 4	- 7
19233...	Nov. 6	18 00	.790		-11.0		
19241...	7	16 48	.057	-65.2	+57.1	+ 8	-25
19244...	7	18 45	.139	-86.4	+95.4	+ 3	- 3
19249...	8	16 03	.184	-72.1	+76.6	+11	-15
19282...	12	18 00	.057	-68.7	+84.0	+ 4	+ 2
19295...	13	18 45	.246	-59.5	+77.6	+ 1	+ 9
V 273...	16	20 11	.781		- 1.6		
277...	17	16 24	.781		+ 8.8		
$\gamma$ 19436...	1933 Jan. 9	14 42	.686	+60.2	-81.6	+ 5	-28
19709...	June 30	22 40	.478	+77.8	-61.1	+ 9	+ 7
V 385...	July 11	0 04	0.437	+64.0	-54.0	+14	- 6

\*  $\gamma$  series: 1-prism spectrograph and 18-inch camera; V series: 3-prism ultra-violet spectrograph and 10-inch camera, except V 86, which was obtained with the 15-inch camera.

Since the interval between the first and last spectrograms corresponds to more than thirty-three hundred orbital revolutions of the binary, the period was assumed to be known. For the correction of the remaining elements, the observations were combined into twelve normal places, weighted according to the number and the quality of the measures involved in each normal. The data for the normals are given in Table III, the last column indicating the plates listed in Table II which enter into each. A least-squares solution by Schles-

TABLE III  
NORMAL PLACES FOR BOSS 35 BR.

No.	PHASE	VELOCITY		RESIDUALS		PLATES INCLUDED
		Prim.	Second.	Prim.	Second.	
	days	km/sec.		km/sec.		
1.....	0.043	-64.9	+64.0	+3	-12	$\gamma$ 19182, 19225, 19241
2.....	.069	-74.4	+87.0	+4	+0	18525, 19226, 19282
3.....	.132	-84.3	+95.3	+5	-3	18508, 19244
4.....	.189	-74.1	+86.4	+8	-5	19072, 19249
5.....	.243	-66.8	+77.7	-5	+8	18556, 19053, 19295
6*	.340	-5.6	.....	+1	.....	18512, 18561, 18642, 19054, 19055, 19083
7.....	.457	+70.9	-57.6	+11	+1	19709; V 385
8.....	.551	+85.4	-78.4	-1	+7	$\gamma$ 18976, 19102, 19156, 19157
9.....	.605	+86.8	-92.3	+3	-9	18517, 19158, 19162, 19163, 19211
10.....	.654	+81.0	-72.8	+11	-4	18497, 18568, 18919
11.....	.687	+54.0	-75.3	-1	-22	V 86; $\gamma$ 19436
12*	0.772	-2.6	.....	-4	.....	V 63; $\gamma$ 18523, 18619, 18656, 18675, 18987, 19060, 19166, 19167, 19178, 19215, 19216, 19233; V 273, 277

\* Omitted from solution for secondary.

inger's method<sup>3</sup> was made for each component, the adopted corrections to the elements being the mean of those given by the two solutions, with double weight in the case of the primary. Modified by these corrections, the elements in Table I give the values adopted as final (Table IV). The corrected elements reduce  $[prv]$  to 44 (primary component) and 59 per cent (secondary component) of the values given by the preliminary elements.

The radial-velocity curves in Figure 1 are based upon the elements in Table IV, adopted as final. The velocity of the system,  $\gamma$ , is indicated by the horizontal line; individual velocities, by circles. The

<sup>3</sup> *Publications of the Allegheny Observatory*, 1, 33, 1908.

residuals given in Table II were read directly from the curves; those in Table III were computed from the final elements.

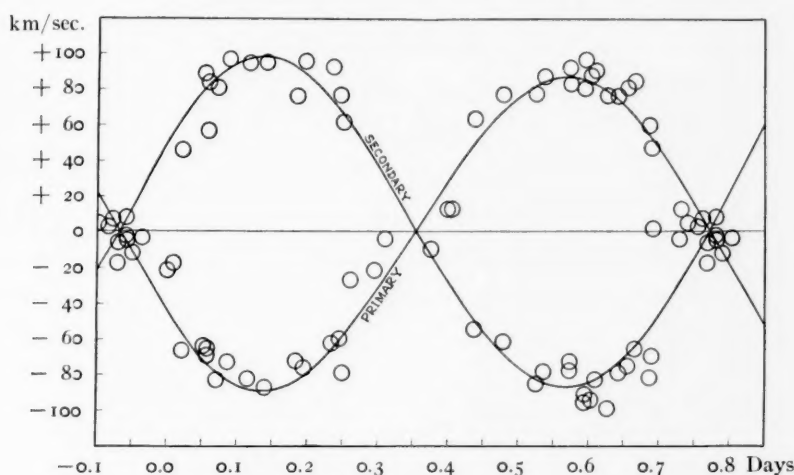


FIG. 1.—Velocity-curve of Boss 35 Br.

The measures of three plates of Boss 35 Br. give no definite indication of variation in radial velocity, the mean value being +7.7 km/sec. The difference between this value and that of  $\gamma$  in Table IV can be accounted for by the probable errors involved and by the possibility of a slight relative linear motion of the two components of  $\Sigma 12$ .

TABLE IV

FINAL ELEMENTS FOR BOSS 35 BR.

$P = 0.84166$ days	$K_1 = 87.96 \pm 1.60$ km/sec.
$T = \text{J.D. } 2426974.104 \pm 0.044$	$K_2 = 92.57 \pm 1.60$
$e = 0.027 \pm 0.016$	$\gamma = +0.37$
$\omega_1 = 119^\circ.55 \pm 18^\circ.84$	$m_1 \sin^3 i = 0.263 \odot$
$\omega_2 = 299.55 \pm 18.84$	$m_2 \sin^3 i = 0.250$
$a_1 \sin i = 1,017,630$ km	
$a_2 \sin i = 1,070,980$	

The absolute magnitudes of the two components of Boss 35 Br. are about +2.0, and, if the mass-luminosity relationship is to be fulfilled, the angle  $i$  must be of the order of  $30^\circ$ , a condition that makes an appreciable eclipse unlikely.

CARNEGIE INSTITUTION OF WASHINGTON  
MOUNT WILSON OBSERVATORY  
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# TEMPERATURE CLASSIFICATION OF INFRA-RED IRON LINES\*

By ARTHUR S. KING

## ABSTRACT

The spectrum of iron from  $\lambda$  6400 to  $\lambda$  10500 has been observed at various temperatures in the electric furnace as well as in the arc. Temperature classification is given for 367 lines, based as far as possible on intensity variation at different furnace temperatures, but also on the widening phenomena of the high-current arc, which indicates the degree of excitation required for lines that do not appear in the furnace spectrum. Prominent line groups belonging to various temperature classes are discussed.

Seventeen iron lines which had been predicted from multiplet structures and which are present in the solar spectrum were identified on arc spectrograms. Twenty-two infra-red solar lines, previously unidentified or of uncertain origin, were found in the present study to be due to iron.

A comparison with the incomplete data available in the infra-red for the sun-spot spectrum shows a distinct tendency of low-temperature lines to strengthen in sun-spots and of high-temperature lines to weaken, in agreement with the condition previously found to hold in the visible spectrum.

A temperature classification of the stronger lines of iron in the visual region was published by the writer in 1913,<sup>1</sup> made according to a plan of classification which has been closely adhered to since that time. A later paper<sup>2</sup> extended the short wave-length region to  $\lambda$  2298. The present list overlaps the first for a short range in the red and extends to  $\lambda$  10470.

The spectrograms were made in the first order of the 15-foot concave grating (scale 1 mm = 3.72 Å). In covering the range of 4000 Å, a variety of Eastman infra-red plates was used. Although these emulsions are being modified from time to time by the Eastman Research Laboratory, it may be useful to note that during the present work the following plates were found most suitable for the ranges indicated:

To $\lambda$ 6850.....	Emulsion I-S <sub>a</sub>
$\lambda\lambda$ 6850-7500.....	Emulsion I-N <sub>a</sub>
7500-8400.....	Emulsion I-R
8400-8800.....	Emulsion I-P
8800-.....	Emulsion I-Q

\* Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington, No. 496.

<sup>1</sup> Mt. W. Contr., No. 66; *Ap. J.*, **37**, 239, 1913.

<sup>2</sup> Mt. W. Contr., No. 247; *Ap. J.*, **56**, 318, 1922.

Extensions of the spectra on each variety of plate, involving only slight decreases in sensitiveness, give good overlaps at each junction.

The vacuum furnace was operated at temperatures from 2100° to 2700° C, the graphite tube being charged with iron filings. The continuous spectrum given by the furnace, due to scattered light from the white-hot wall of the tube, proved more of an obstacle to the photography of the fainter furnace lines than at shorter wavelengths and prevented the use of prolonged exposures. Consequently, the infra-red lines registered in the furnace spectrum are those which a considerable proportion of the atoms present are able to emit, and lines which might be brought out by long exposure are not visible on the plates under these conditions.

It was therefore necessary to supplement the furnace data with other evidence indicating the probable temperature classes of the weaker lines. The writer's previous study<sup>3</sup> of iron lines given by the high-current arc, in which the widening of iron lines between  $\lambda$  4250 and  $\lambda$  8388 was observed in the spectrum of an explosive arc carrying a current of about 1000 amp, proved useful for this purpose. It was found that in the visible region, where temperature classification and high-current arc phenomena could be directly compared, low-temperature lines remained sharp or showed only slight widening, while those requiring high excitation either became diffuse or widened very unsymmetrically, usually toward greater wave-length. A comparison of the infra-red furnace spectrograms now available with those of the high-current arc showed that the same relation holds at greater wave-lengths. It was therefore assumed that faint lines which remain sharp in the high-current arc would appear in the furnace if strong furnace spectra were obtainable. Such lines have been placed provisionally in class IV, an asterisk denoting the basis of the classification. For the region beyond that covered by the 1000-amp arc, account was taken of the degree of sharpness of lines in the continuous-current arc, operated at 20 amp, and, as infra-red lines are very sensitive to widening influences, the lines whose levels are probably not high could be selected. Excitation

<sup>3</sup> *Mt. W. Contr.*, No. 298; *Ap. J.*, **62**, 238, 1925.

potentials of lines in known multiplets, for a list of which I am indebted to Miss C. E. Moore, gave another means of selecting lines of medium energy levels which are invisible in the furnace spectrum.

The wave-lengths in the first column of Table I are for the most part those of Burns<sup>4</sup> and of Meggers and Kiess,<sup>4</sup> with a few measured by the writer. In order to do justice to the large intensity differences, the scale of arc intensities in the second column is much more open than in the early paper on the visible spectrum. Lines with "n" after the intensity number are more or less diffuse in the arc and are always associated with high energy levels. Some close doublets were detected, even with the moderate resolution used, and a uniform widening of other lines indicated probable doublet structure.

The furnace intensities in the third column are from high-temperature spectrograms. Intensity estimates of furnace lines are in some cases uncertain, owing to coincidences with lines belonging to easily excited bands of the CN molecule, arising from the small residue of air in the furnace. However, a comparison with plates made for the bands alone, with nitrogen passing through the empty carbon tube, usually showed the approximate intensity of coincident iron lines.

The class numbers in the last column have the usual significance, except that, as already noted, lines designated as of class IV\* have not appeared in the furnace spectrum, but are believed on other grounds to belong to medium energy levels. "A" after the class number indicates that the line is relatively faint in the arc, which in the infra-red is true for only a few low-temperature lines.

Explanatory notes are placed at the end of the table, and are referred to by a dagger (†) adjacent to the wave-length.

<sup>4</sup> Summarized by Kayser, *Handbuch der Spectroscopie*, 7 (1); also Meggers and Kiess, *Bur. Stand. Jour. of Research*, 9, No. 473, 1932.

TABLE I  
TEMPERATURE CLASSIFICATION OF IRON LINES

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
6393.609.....	400	100	II	6705.139.....	15n		V
6400.021.....	800	10	IV	6710.31†.....	2	?	III?
6400.335†.....	?	50	I A	6713.14†.....	6d		V
6408.044.....	60		V	6713.76.....	3n		V
6411.125†.....	1n		V	6715.410.....	5		V
6411.674.....	400	5	IV	6716.24.....	3		IV*
6419.988.....	30n		V	6717.556.....	3		V
6421.361.....	200	80	II	6725.39.....	2		V
6430.859.....	300	125	II	6726.668.....	20n		V
6462.737.....	30	15	II	6732.06.....	1		IV*
6469.216.....	15n		V	6733.171.....	6		V
6475.635.....	12	2	IV	6738.08†.....	4n		V
6481.881.....	20	5	III	6739.54.....	1	3	III A
6494.993.....	1000	300	II	6745.11.....	1		IV*
6495.796.....	3		V	6750.163.....	100	30	III
6496.462.....	20n		V	6752.734.....	10		V
6498.950.....	5	40	II A	6755.609.....	3		IV*
6501.681.....	4		IV*	6777.44.....	1		V
6516.08†.....	1		V	6783.71.....	2		IV*
6518.380.....	20	3	IV	6786.88.....	5		V
6528.53.....	2		V	6793.26.....	2		V
6533.97.....	8n		V	6793.62†.....	1		V
6546.251.....	200	60	III	6796.11.....	2		V
6569.233.....	50n		V	6804.020.....	5		V
6574.238.....	3	20	II A	6804.27.....	3		IV*
6575.028.....	30	3	IV	6806.859.....	10	1?	IV
6581.22†.....	2	?	III ?	6810.28.....	20n		V
6591.32.....	2		V	6819.606†.....	1		V
6592.928.....	300	100	III	6820.43.....	8n		V
6593.881.....	60	25	III	6822.053†.....	1-		V
6597.607.....	15n		V	6828.614.....	50		V
6608.03.....	2		IV*	6833.24.....	1		V
6609.124.....	30	5	III	6837.00.....	3		IV*
6609.56.....	1		V	6838.86.....	3n		V
6613.817†.....	1-	2	III A	6839.828.....	4		IV*
6625.04.....	1	5	II A	6841.362.....	80		V
6627.563.....	5		V	6842.668.....	6n		V
6633.436†.....	4n		V	6843.685.....	60		V
6633.772.....	50		V	6844.695†.....	1-	1?	III A?
6634.132†.....	4n		V	6847.615†.....	1-		V
6639.726†.....	4		V	6851.664†.....	1-		IV*
6639.906†.....	2		V	6854.82.....	2		IV*
6648.130†.....	1-	8	II A	6855.183.....	150		V
6663.452.....	80	30	III	6855.74.....	2		V
6667.464†.....	1-		IV*	6857.25.....	4		IV*
6678.001.....	600	200	III	6858.173.....	40		V
6699.14.....	2		V	6860.29.....	1		IV*
6703.570.....	10	1	IV	6860.965†.....	1-		IV*
6704.509†.....	1		V	6861.93.....	2		IV*

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
6862.481	4n		V	7145.317	5		V
6875.45	1		IV*	7151.495	1		IV*
6875.98	1		IV*	7155.64	3n		V
6880.65	2		V	7158.502	1		V
6881.46†	1		V	7164.480	250		V
6881.74†	1		V	7175.937	3		V
6885.77	20		V	7176.886	2n		V
6898.31	3		V	7180.020	1		IV*
6902.80	3n		V	7181.22	10		V
6911.52	1		IV*	7181.93	1n		V
6916.710	60		V	7187.349	800	2	V
6930.64	1		V	7189.17	3		IV*
6933.052†	1		V	7194.92	1		V
6933.632†	6	?	IV*	7207.123	6		IV*
6945.215	150	40	III	7207.430	500		V
6947.501	3		V	7212.47	1n		V
6951.278	25		V	7219.608	5		IV*
6951.647†	1		V	7221.22	2n		V
6960.334	2		V	7223.678	12		IV*
6971.95	1		IV*	7228.69	1		IV*
6975.46	3n		V	7239.904	6		V
6976.306	1		V	7244.86	2n		V
6976.934	3		IV*	7254.649	2		IV*
6977.445	4		IV*	7256.132†	1		V
6978.864	100	25	III	7261.54	3n		V
6988.541	5		IV*	7282.39	1n		V
6990.928	30		V	7284.853	4		IV*
7000.633	3		IV*	7285.286	1		V
7008.014	5		V	7288.782	10		V
7010.362	2		IV*	7292.856	3n		V
7011.364	3		IV*	7293.093	15		V
7016.075	20		IV*	7295.00	1		V
7016.436	60		V	7300.47	1n		V
7023.003	50		V	7306.61	3		V
7024.084	5		IV*	7307.957	8		IV*
7024.649	10n		V	7311.112	12		V
7038.257	40		V	7320.72	5n		V
7038.818	2		V	7333.62	1n		V
7068.422	40		IV*	7351.160	2n		V
7069.557†	1		IV*	7351.56	4		V
7071.88	1		V	7353.528	1		V
7083.396	1n		V	7363.96	1n		V
7086.76	2		V	7366.37	1		V
7090.417	40		V	7370.16	1		V
7095.447	3		V	7376.38	3n		V
7107.486	4		IV*	7382.99	1n		V
7112.182	3		IV*	7386.402	8n		V
7130.956	150		V	7389.432	80		V
7132.999	8		IV*	7401.707	4		IV*
7142.522	4n		V	7411.196	100		V

INFRA-RED IRON LINES

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TABLE I—Continued

λ	INTENSITY		CLASS	λ	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
7418.680	5		IV*	8096.85	10		IV*
7421.60	1-		V	8145.47	4		V
7430.73	1-		IV*	8149.59	3		V
7440.98	2n		V	8186.80†	10n		V
7443.022	2		IV*	8199.00†	80	?	V
7445.783	200		V	8207.85	40		V
7447.43	1		V	8220.422	1500	2	V
7491.678	12		V	8232.36	50		V
7495.090	400		V	8239.09	8		IV*
7498.56	1		IV*	8248.16	30		V
7507.31	8		V	8264.27†	3		V
7511.059	800	2	V	8274.28†	6	?	IV?
7531.181	60		V	8275.91	4n		V
7546.173	4		IV*	8293.47	20		V
7559.68	1n		V	8327.080	1200	400	II
7563.03	1n		V	8332.01	200		V
7568.932	30		V	8339.41	80		V
7573.53	2n		V	8360.79	8		V
7583.803	50		IV*	8365.50†	25	?	IV?
7586.060	150	1?	V	8387.785	1200	400	II
7605.32	2n		V	8401.42	2		IV*
7620.531	25		V	8422.95	2		V
7653.80	6		V	8424.14	2n		V
7661.24	30		V	8439.58	20		V
7664.303	80	I	IV	8446.40†	4n		V
7710.40	25		V	8468.427	300	100	II
7723.20	4		IV*	8471.75	2		V
7742.71	4n		V	8497.00	8		V
7748.280	125	6	IV	8514.11	150	50	II
7751.18	5n		V	8515.08	20		IV*
7780.594	300		V	8526.66	8		V
7808.04	6n		V	8582.20	15		IV*
7832.243	400	2	V	8592.97	2n		V
7844.66	2		V	8598.79	4		V
7855.48	4n		V	8611.73	40	5	III
7869.65	4		V	8621.55	10		IV*
7879.84	1		V	8661.920	600	200	II
7912.85†	6	10?	II A	8674.69	60	5	III
7937.182	700		V	8688.640	1500	500	II
7941.09	10		IV*	8699.43	4n		V
7945.880	600		V	8710.29	8n		V
7994.48	20		IV*	8713.19	2		V
7998.986	700		V	8757.16†	25	2?	IV
8024.50	3n		V	8764.02	20n		V
8028.37	50		V	8784.44	1n		V
8046.087	600		V	8790.62	1n		V
8047.60†	15	15?	II	8793.38	25n		V
8075.13†	4	4?	II	8804.56†	3	2?	IV*
8080.62†	10n		V	8824.18	250	100	II
8085.219	500		V	8838.36	30		IV*

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		* CLASS
	Arc	Furnace			Arc	Furnace	
8846.82	2n		V	9394.71	1n		V
8866.92	60		V	9401.09	6n		V
8868.42	3		IV*	9414.14	8n		V
8876.13	2		IV*	9430.07	3		IV*
8916.26	1	2	II A	9443.98	6n		V
8919.95	4		V	9452.45	1		V
8929.04	2n		V	9454.24	2n		V
8943.00	2		IV*	9462.97	2n		V
8945.15	10n		V	9513.21	8n		V
8975.36	10		IV*	9529.31	2n		V
8984.87	2		V	9569.95	15n		V
8999.54	200	10	III	9626.60	12n		V
9010.55	1		IV*	9634.22	4n		V
9012.10	10		V	9637.55	2		V
9024.47	4n		V	9653.18	15		V
9079.65	4		V	9657.30	3n		V
9088.22	50		IV*	9666.59	2		V
9089.40	30		IV*	9699.70	4		V
9100.50	2n		V	9738.73	100		V
9118.87	25		IV*	9753.15	10		V
9146.11	2		IV*	9763.34	10		V
9147.91	2n		V	9763.91	12		V
9210.02	6		IV*	9783.96	3		V
9214.45	4n		V	9800.42	8n		V
9217.54	2n		V	9834.04	2n		V
9246.54	2		IV*	9861.83	12		V
9258.40	10n		V	9868.09	3		V
9259.05	4		V	9889.11	15		V
9294.66	1		V	9917.93†	2		IV*
9318.13	1		V	10057.64	3		V
9343.40	2n		V	10065.09	30		V
9350.52	6		V	10145.64	40		V
9359.37	3		IV*	10216.42	50		V
9362.36	4		IV*	10469.55	10		V
9372.84	6		IV*				

## NOTES TO TABLE I

$\lambda$	
6400.335	Blend in arc with $\lambda$ 6400.021.
6411.125	Solar $\lambda$ . Predicted <i>Fe</i> line.
6516.08	Ascribed to <i>Fe</i> <sup>+</sup> .
6581.22	Blend CN in furnace. Low EP indicates class III.
6613.817	Solar $\lambda$ . Predicted <i>Fe</i> line.
6633.436	Solar $\lambda$ . Diffuse arc line, measured $\lambda$ 6633.44.
6634.132	Solar $\lambda$ . Predicted <i>Fe</i> line.
6639.726	Solar $\lambda$ 's. Unresolved arc doublet, measured $\lambda$ 6639.803. Width would account for both solar lines. $\lambda$ 6639.726 is predicted <i>Fe</i> line.
6639.906	

6648.130	Solar $\lambda$ . Predicted <i>Fe</i> line.
6667.464	Solar $\lambda$ . Predicted <i>Fe</i> line.
6704.509	Solar $\lambda$ . Predicted <i>Fe</i> line.
6710.31	Blend <i>CN</i> in furnace. Low EP indicates class III.
6713.14	Components about 3:1.
6738.08	Shaded in arc toward longer waves.
6793.62	Measured by writer.
6819.606	Solar $\lambda$ . Predicted <i>Fe</i> line.
6822.053	Solar $\lambda$ . Predicted <i>Fe</i> line.
6844.695	Solar $\lambda$ . Predicted <i>Fe</i> line. Very faint. Probably present in arc and furnace.
6847.615	Solar $\lambda$ . Predicted <i>Fe</i> line.
6851.664	Solar $\lambda$ . Predicted <i>Fe</i> line.
6860.965	Solar $\lambda$ . Predicted <i>Fe</i> line.
6881.46	Measured by writer. Solar line at $\lambda$ 6881.470; not identified.
6881.74	Measured by writer. Solar line at $\lambda$ 6881.726; identified as <i>Cr</i> , but probably chiefly <i>Fe</i> .
6933.052	Solar $\lambda$ . Predicted <i>Fe</i> line.
6933.632	Coincides <i>CN</i> in furnace. May be present.
6951.647	Solar $\lambda$ . Predicted <i>Fe</i> line.
7069.557	Solar $\lambda$ . Predicted <i>Fe</i> line.
7256.132	Solar $\lambda$ . Predicted <i>Fe</i> line.
7912.85	Coincides <i>CN</i> in furnace. Approximate intensity of band line subtracted.
8047.60	Similar to $\lambda$ 7912.85.
8075.13	Similar to $\lambda$ 7912.85.
8080.62	May be double.
8186.80	May be double.
8199.00	Coincides <i>CN</i> . Very faint if present.
8264.27	Measured by writer.
8274.28	Nearly coincides <i>CN</i> . May be present in furnace. Solar line at $\lambda$ 8274.353 strong in sun-spot spectrum.
8365.59	Coincides <i>CN</i> . May be present in furnace.
8446.40	Measured by writer.
8757.16	Furnace line may belong to band.
8804.56	Furnace line may belong to band. Line has medium EP.
9917.93	Furnace line may belong to band.

## DISCUSSION

In the first part of Table I, which covers a region included in the earlier publication, improved photographic plates have permitted the classification of many additional lines. Some strong lines previously placed in class III have been changed to class II, owing to a condition which will probably make similar changes in the classes of orange and red lines advisable when the old classification of the visible spectrum is revised. According to the regular plan of classification, lines strong in the arc and retaining fair intensity

at low temperature go into class II; but in the red region a higher initial temperature is required to bring out such lines than to record class II lines in the blue. The reason is seen at once in the excitation potentials, usually near 2.2 volts for red lines of this type, while the prevailing value for class II lines of shorter wave-length is about 1.5 volts. The temperature classification is most useful when stages are chosen such as to make the grouping of lines at different temperatures as distinct as possible, rather than to retain a close correspondence with excitation potential throughout the spectrum.

New data concerning members of the low-level multiplet  $a^5F - z^7F^o$ , with an excitation potential of about 1.0 volt, were obtained during the present work. Two of these,  $\lambda 6280.63$  and  $\lambda 6358.69$ , were previously noted as class IA lines.  $\lambda 6400.335$  is similar to these lines, but is blended on the earlier plates with a strong neighbor,  $\lambda 6400.021$ , so that its low-temperature character was not recognized. Five other lines of this multiplet,  $\lambda\lambda 6498.95$ ,  $6574.24$ ,  $6613.82$ ,  $6625.04$ ,  $6648.13$ , not quite so strong at low temperature, appear on the present plates. All are very faint in the arc, and two are entered in the multiplet by Miss Moore<sup>5</sup> as "predicted." Resembling these lines are  $\lambda\lambda 7912.85$ ,  $8047.60$ ,  $8075.13$ , which are clearly present but happen in each case to form blends in the furnace with lines belonging to the CN band structure.

Other distinctive furnace lines in the infra-red, strong also in the arc, are members of two multiplets,  $a^5P - z^5P^o$  and  $b^3P - z^3P^o$ , given in Table II.

Many other strong lines occur between  $\lambda 7000$  and  $\lambda 10500$ , but they are uniformly associated with high levels. A large proportion of the weaker lines in this region, however, show a sharpness in the arc which justifies placing them in class IV\*. Their excitation potentials are in many cases unknown, and it is quite possible that some may be members of class III multiplets.

#### PREDICTED IRON LINES

In the *Revised Rowland*, a large number of solar lines were found to have wave-lengths corresponding to those of iron lines calculated from the multiplet structures of iron, although not observed in the

<sup>5</sup> *A Multiplet Table of Astrophysical Interest*, 1933.

laboratory. In the solar table<sup>6</sup> these are entered as "predicted" iron lines. In the range covered by Table I, the writer has found 17 of these lines on strong arc spectrograms, identifying them by means of a glass scale which reads wave-lengths to 0.1 Å. In nearly all

TABLE II  
DISTINCTIVE LOW-TEMPERATURE LINES  
OF THE INFRA-RED

$\lambda$	Class	EP	Multiplet
8327.080.....	II	2.188	$a^5P_2 - z^5P_1^0$
8387.785.....	II	2.167	$a^5P_3 - z^5P_2^0$
8468.427.....	II	2.213	$a^5P_1 - z^5P_1^0$
8514.11.....	II	2.188	$a^5P_2 - z^5P_2^0$
8661.920.....	II	2.213	$a^5P_1 - z^5P_2^0$
8688.640.....	II	2.167	$a^5P_3 - z^5P_3^0$
8824.18.....	II	2.188	$a^5P_2 - z^5P_3^0$
8611.73.....	III	2.833	$b^3P_1 - z^3P_0^0$
8674.60.....	III	2.819	$b^3P_2 - z^3P_1^0$
8757.16.....	IV	2.833	$b^3P_1 - z^3P_1^0$
8838.36.....	IV*	2.846	$b^3P_0 - z^3P_1^0$
8999.54.....	III	2.819	$b^3P_2 - z^3P_2^0$
9088.22.....	IV*	2.833	$b^3P_1 - z^3P_2^0$

cases, either the faintness of these lines or their nearness to strong lines, necessarily overexposed, prevented satisfactory micrometer measures. The solar wave-lengths of the predicted lines have therefore been used in Table I. The list is given in Table III.

TABLE III

$\lambda$ 6411.125	$\lambda$ 6667.464	$\lambda$ 6844.695	$\lambda$ 6933.052
6613.817	6704.509	6847.615	6951.647
6634.132	6819.606	6851.664	7069.557
6639.726	6822.053	6860.965	7256.132
6648.130			

IDENTIFICATION OF ADDITIONAL IRON LINES  
IN THE SOLAR SPECTRUM

While most of the lines in Table I are ascribed in the *Revised Rowland* to iron, those listed in Table IV are not so identified, and in most cases are quite without identification. The agreement between solar and arc wave-lengths appears to be close enough, how-

<sup>6</sup> See also *ibid.*

ever, to justify the assumption that the solar lines of the latter list are due to iron.

TABLE IV

SUN		ARC	
$\lambda$	Int.	$\lambda$	Int.
6633.436.....	o	-----*	4n
6639.906.....	-1N	-----†	2
6737.987.....	o	6738.08‡	4n
6793.638.....	oN(I?)	6793.62	1
6881.470.....	-1	6881.46	1
6881.726§	o(Cr)	6881.74	1
8198.984§	1(atm)	8199.00	8o
8264.272.....	-2	8264.27	3
8446.350.....	o	8446.40	4n
8868.445.....	1	8868.42	2
8876.027.....	-2	8876.13	2
8943.074.....	-1	8943.00	2
8984.919.....	-2	8984.87	2
9010.60.....	-2	9010.55	1
9463.03.....	-1	9462.97	2n
9699.68.....	-1	9699.70	4
9861.88.....	o	9861.83	12
9889.20.....	-1	9889.11	15
10057.9.....	-2	10057.64	3
10065.1.....	-1	10065.09	30
10145.8.....	o	10145.64	40
10216.2.....	1	10216.42	50

\* Diffuse arc line measured  $\lambda$  6633.44 (difficult).

† Long-wave component of doublet  $\lambda$  6639.803.

‡ Arc line shaded toward longer waves.

§ Solar line is probably partly Fe.

#### COMPARISON WITH SUN-SPOT LINES

In the *Revised Rowland*, relative intensities for lines in the solar disk and in sun-spots are given as far as  $\lambda$  8850. With the plates now available, greatly improved spectrograms for the infra-red may be expected during the next sun-spot cycle. As a preliminary comparison, however, Table V shows the percentages of the iron lines of each temperature class in Table I whose presence in sun-spots has been observed, grouped according as they are weakened, unchanged, or strengthened in passing from disk to spot spectrum.

The strengthening of low-temperature and the weakening of high-temperature lines in passing from disk to spot, a condition prevailing

throughout the visible spectrum, is thus found to be distinct in the infra-red region also. The scattering from type will probably be reduced when the solar material is revised. Lines of class II in Table I in general show a very decided strengthening in sun-spots,

TABLE V  
CHANGE OF INTENSITY FROM SOLAR DISK TO SPOT FOR  
LINES OF DIFFERENT TEMPERATURE CLASSES

Class	No. Lines Compared	Weakened	Unchanged	Strengthened
		per cent	per cent	per cent
II.....	19	None	16	84
III.....	15	None	33	67
IV.....	59	34	32	34
V.....	141	54	33	13

while those of classes IV and V, when strengthened at all, are rarely changed by more than one unit. The tendency of high-temperature lines to weaken in the spot spectrum appears, from the present material, to be less pronounced for very strong lines. Of the class V lines with intensity 100 or greater, only one is weakened in the spot, while seven are unchanged and seven slightly strengthened.

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## A PRELIMINARY SURVEY OF THE ZEEMAN EFFECT IN THE SUN-SPOT SPECTRUM\*

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### ABSTRACT

A preliminary study of the Zeeman effect in the sun-spot spectrum based on Mount Wilson plates and mostly on measures made at Mount Wilson and lent to the author. The spectrograms include observations on six different spots. Since no common determination of field-strength by means of the iron line  $\lambda 6173$  was available, the spectral regions from different spots have been treated separately.

A blending effect, probably caused by the inclination of the lines of force in the spot to the line of sight, which tends to reduce the apparent field-strength, is revealed by frequency distribution-curves of the apparent field-strengths shown by different lines. This effect is at a maximum in the violet and a minimum in the red. A "selected list" of 416 lines has been prepared for which this effect should be much diminished.

The apparent correlation between spot intensity of lines and field-strength is confirmed for the average of all lines, the field-strength decreasing with increasing line intensity. The correlation is much weaker for the selected lines to the violet of  $\lambda 6000$ , and vanishes for those to the red. Complicated effects of blending and observational selection leave the question of correlation between true field-strength and line intensity an open one. Enhanced lines give smaller field-strengths than arc lines of the same spot intensity.

A correlation between Evershed effect and field-strength is found for 258 lines; but Evershed effects are found to be more closely correlated with disk intensities, while field-strengths are better correlated with spot intensities.

The question of variation of field-strength with level is discussed. The relative levels of different elements indicated by the field-strengths found from lines of the same spot intensity differ somewhat from those of St. John based on disk intensities. Allowance for intensity differences between disk and spot spectra improves the agreement.

No relation has been found between the field-strength or the character of the Zeeman patterns and the noteworthy strengthening in the spot spectrum of faint satellite lines in many multiplets.

### INTRODUCTION

In 1908 Dr. George E. Hale announced his very important discovery of the existence of strong magnetic fields in sun-spots.<sup>1</sup> He proved the existence of these fields and measured their strength by means of the Zeeman effect of atomic lines in the spot spectrum. The magnetic separations in the spot spectrum were compared with those in laboratory spectra for numerous lines of *Fe*, *Ti*, and *Cr*, the Zeeman effects for these lines being especially investigated for the purpose.

The present investigation, the first extensive study of the Zeeman

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<sup>1</sup> *Mt. W. Contr.*, No. 30; *Ap. J.*, **28**, 315, 1908.

effect of atomic lines in the spot spectrum since Dr. Hale's original work, was undertaken for the following reasons:

First, a great mass of spectroscopic material, both theoretical and observational, has become available during the last decade. Of special importance is the Landé theory, which has very successfully accounted for the "anomalous" Zeeman effect and provided a basis for predicting the Zeeman patterns of spectral lines whose multiplet designations are known.

Second, through the kindness of Dr. Walter S. Adams, a long series of measures of the Zeeman separations of sun-spot lines, made at Mount Wilson ten years ago but not previously discussed, was placed at the disposal of the writer. These data have been supplemented by additional measures on the original negatives and on an excellent set of contact-print plates by Mr. Ferdinand Ellerman.

This accumulated material justifies a new attack on the problem; but because of the many complicated features exhibited by the Zeeman effects of sun-spot lines, the present work must be considered as only a general preliminary survey and an attempt to point the way for further investigation.

#### I. OBSERVATIONAL DATA

The photographs of the sun-spot spectrum used in this investigation were taken at Mount Wilson with the 150-foot tower telescope and 75-foot spectrograph during the years 1915-1917, and are those from which the well-known Mount Wilson map of the sun-spot spectrum was printed.<sup>2</sup> Table I gives the relevant data on the six spots used in obtaining the plates. The spectrograms cover the visual region,  $\lambda\lambda$  3900-5400 in the third order and  $\lambda\lambda$  5400-6630 in the second order. A nicol prism and compound quarter-wave plate mounted above the slit of the spectrograph allowed the Zeeman components circularly polarized in opposite directions to appear on adjacent longitudinal strips in the photograph.<sup>3</sup> Spectral lines emitted or absorbed in a magnetic field and viewed parallel to the lines of force with this equipment should, theoretically, show only their circularly polarized  $\sigma$  components. If the field is viewed at an angle, however

<sup>2</sup> Hale and Ellerman, *Pub. A.S.P.*, **32**, 272, 1920.

<sup>3</sup> Hale, *Mt. W. Contr.*, No. 71; *Ap. J.*, **38**, 27, 1913.

(i.e., with the lines of force in the spot not parallel to the line of sight), the light of the  $\sigma$  components will be elliptically polarized and the polarizing device will not totally extinguish either of the groups of  $\sigma$  components.<sup>4</sup> This effect, which is found to have an important influence on the present work, is discussed in section 3. For the spots observed the angle between the normal to the spot and the line of sight, as determined from the position of the spot given in the *Greenwich Photoheliographic Catalog*, appears in the fourth column of Table I.

TABLE I  
DATA ON SUN-SPOTS

Region	Greenwich Spot No.	Date	Angle	Field-Strength
				gausses
$\lambda\lambda$ 3900-4700.....	7926	Jan. 4, 1917	22°	2730
4700-5100.....	7977	Feb. 7, 1917	27	2690
5100-5400.....	7977	Feb. 13, 1917	53	2250
5400-5550.....	7708	May 5, 1916	15	2210
5500-5850.....	7727	May 20, 1916	13	2620
5850-6000.....	7709	May 3, 1916	33	2340
6000-6150.....	7330	July 12, 1915	29	2690
6150-6300.....	7330	July 11, 1915	25	
6300-6450.....	7330	July 12, 1915	29	
6450-6650.....	7977	Feb. 8, 1917	16	2740

The last column of Table I gives the field-strengths determined from a list of the best lines selected by the writer. These will be discussed later.

## 2. MEASURES AND REDUCTIONS

With the exception of four vanadium lines in the red, all the observed patterns for the  $\sigma$  components on each side of the center are unresolved and appear as blends. The separations of the centers of gravity of these groups of blended  $\sigma$  components in adjacent strips of the spectrum were measured at Mount Wilson in 1921-1922 by Miss B. W. Mayberry ( $\lambda\lambda$  4700-6600 and a number of selected lines between  $\lambda\lambda$  3900-4700) and by Professor H. C. Wilson ( $\lambda\lambda$  4500-4700).<sup>5</sup> On the contact-print plates made from the originals the writer has measured all usable lines between  $\lambda$  3900 and  $\lambda$  4500 and

<sup>4</sup> Hale, Ellerman, Nicholson, and Joy, *Mt. W. Contr.*, No. 165; *Ap. J.*, **49**, 153, 1919.

<sup>5</sup> Unpublished material.

numerous lines omitted from the earlier work in other regions, and has checked many of the earlier measures. As far as could be ascertained, there seems to be no systematic difference between the various sets of measures finally used, although some of those in the violet region were rejected because of discrepancies. These rejected measures had been made on strips covering parts of the spot that did not show the maximum magnetic effect. Owing to the diffuse and uncertain character of the majority of the lines, the discordances between individual settings on a line were, in most cases, rather large.

After conversion into  $\text{cm}^{-1}$ , the measured separations of the unresolved  $\sigma$  patterns were used to derive relative apparent field-strengths. This calculation was based on the fact that the center of gravity of an unresolved group of Zeeman components is at a point one-fourth of the distance from the strongest to the weakest component.<sup>6</sup> When the multiplet designation of a line is known, the Landé theory gives the description of the Zeeman pattern. Tables of the Zeeman patterns of all types of observable multiplets are available,<sup>7</sup> from which the distance  $B_\sigma$  from the undisplaced center of the pattern to the center of gravity of the unresolved  $\sigma$  components can be derived in terms of the standard unit. Experience has shown that in general the method is reliable for unresolved groups of  $\sigma$  components of laboratory absorption lines. For very faint laboratory lines, however, the strongest component of the  $\sigma$  group is often the only one visible. For sun-spot patterns, which are broad, diffuse, and unresolved, the method should also be satisfactory when the patterns are not complicated by spurious effects.

A quantity  $R$ , proportional to the strength of the magnetic field acting on a given spot line, is given by the ratio of the observed separation of groups of unresolved  $\sigma$  components (reduced to wave-numbers) to the value  $B_\sigma$ :

$$R = \frac{\Delta\nu}{B_\sigma}.$$

The field-strength in gaussses is, then,  $10,630R$ . In the present work it is more convenient, however, to use the value of  $R$  itself.

<sup>6</sup> Shenstone and Blair, *Phil. Mag.*, **8**, 765, 1929.

<sup>7</sup> Kiess and Meggers, *Bur. Stand. Jour. of Research*, **1**, 641, 1928.

It is also convenient to treat the complex Zeeman patterns observed in the sun-spot spectrum as triplets, the groups of unresolved  $\sigma$  components on either side of the center being referred to as the " $\sigma$  components" and the unresolved  $\pi$  components as the " $\pi$  component." This procedure is justifiable since in only four cases are the individual  $\sigma$  components resolved in the spot spectrum.

The available laboratory Zeeman effects for *Fe*, *Cr*, *Ti*, *Ti*<sup>+</sup>, *V*, *Zr*, *Zr*<sup>+</sup>, *Sc*, *Sc*<sup>+</sup>, *Mn*, *Ca*, *Y*, *Y*<sup>+</sup>, *Cu*, *Mo*, and *La*<sup>+</sup> were compared with the theoretical patterns, or, when the laboratory patterns were unresolved, with  $B_\sigma$ . When the theoretical and observed patterns differed, usually on account of abnormal  $g$  values, the  $R$ 's were obtained for both patterns. A few  $R$  values based on theoretical  $B_\sigma$ 's which were very far from the mean for the spot were thus brought into much better accordance with the mean, and vice versa. Most of them, however, showed only small differences, and no systematic effects were noticeable.

### 3. FREQUENCY DISTRIBUTION OF $R$

The frequency distribution of the values of  $R$  is significant. In general two maxima occur, one ( $A$ ) for high values of  $R$  and one ( $B$ ) for low values. In the red, only maximum  $A$  appears, and in the violet, only  $B$ , with a continuous transition between—that is,  $A$  diminishes and  $B$  increases in magnitude in passing from red to violet.  $A$  occurs for a value of  $R$  corresponding to a field-strength of the order of that estimated from the size of the spot, while for  $B$  the  $R$  value is about one-third as large.

Without any polarizing apparatus, lines with large magnetic separations would appear double, and those with small separations would be only widened. Thus strong lines appear as doublets only when  $B_\sigma$  is large, and then only in the red, owing to the dependence of the observed separation on  $\lambda^2$ . In the red almost all weak lines will appear double. In the violet, however, only weak lines with large  $B_\sigma$  will be resolved. The measured separation of lines whose  $\sigma$  components are clearly separated in adjacent longitudinal strips with the polarizing apparatus will not be affected by the overlapping disk spectrum, which is always present in some degree, particularly in the violet, because of poor seeing and of scattering in the solar atmos-

phere and in the instrument. The measured separation of lines that are not clearly separated in adjacent strips will, however, be diminished by this blending effect. The same effect is produced on lines which are not separated in adjacent strips when the lines of force in the spot make a considerable angle with the line of sight, thus allowing both  $\sigma$  components and the  $\pi$  component to appear in the same strip. The observed  $R$  values strongly suggest that an influence of this kind is at work, for when the frequencies for lines with wide magnetic separations ( $B_{\sigma} \geq 1.50$ ) are plotted, the number of lines contributing to  $B$  is greatly diminished, while  $A$  is little affected.

Additional evidence is furnished by plotting  $R$  against  $B_{\sigma}$ , separately for lines in different spectral regions and with different spot intensities. It is thus found that in the region  $\lambda\lambda$  6000–6450 lines of spot intensity greater than 7 on the Rowland scale fall into two groups, one with small values of both  $R$  and  $B_{\sigma}$  and one with large values of both, a result indicating that the apparent field-strength, for strong lines at least, depends on the magnitude of the Zeeman separation. In the red region practically all the small values of  $R$  belong to very strong lines; hence the plots for weaker lines show a single group of points clustered about a high mean value of  $R$ . Strong lines in regions to the violet of  $\lambda$  6000 fall into a single group of low mean  $R$ , regardless of the size of  $B_{\sigma}$ . Weaker lines fall into a single group whose mean  $R$  has a higher value.

The conclusion that some blending effect is operating is supported by the appearance of many lines whose components are clearly separated in adjacent strips. For these lines both violet and red  $\sigma$  components are often present in the same strip, one strong and the other weak, owing to the elliptical polarization of the incident light.<sup>4</sup> In addition, many lines also show an undisplaced component, apparently the  $\pi$  component. The spots used for the present work were not at the center of the disk when photographed, and it is not surprising that these additional components should appear. Lines can be found for which the weaker  $\sigma$  component is in various stages of resolution from the stronger  $\sigma$  component in the same strip (e.g., see the *Fe* lines  $\lambda\lambda$  6302.508, 6301.517, 6297.808 in the Mount Wilson map of the sun-spot spectrum). If the weaker  $\sigma$  component and the  $\pi$  component are not resolved, that is, if the stronger  $\sigma$  components

overlap in adjacent strips, the effect will be to widen the stronger  $\sigma$  component on the side toward the center, thus reducing the measured separation and the value of  $R$ .

The relative intensities of the three components of a normal triplet for one strip are proportional to<sup>8</sup>

$$\sigma_v = \frac{1}{4}(1 - \cos \gamma)^2, \quad \pi = \frac{1}{2} \sin^2 \gamma, \quad \sigma_R = \frac{1}{4}(1 + \cos \gamma)^2,$$

where  $\gamma$  is the angle between the line of sight and the lines of force. The largest value of  $\gamma$ , for spot No. 7977 (February 13, 1917), is  $53^\circ$ , whence

$$\sigma_v = 0.039, \quad \pi = 0.319, \quad \sigma_R = 0.642.$$

The actual problem is complex, however, since the magnetic axis of a spot is often known to differ considerably from the physical axis and since the angle of the lines of force changes rapidly across the spot.<sup>4</sup> Hence the angle at which the lines of force are viewed may be appreciably different for parts of the spot appearing in adjacent strips of the spectrum. Unless the variation of the angle of the lines of force has been determined for each spot used, no corrections can be applied even though the position and orientation of the spot on the slit of the spectrograph are known. In addition, the effect of scattered light would be similar to that of the blended  $\pi$  and  $\sigma$  components and would reduce the measured separation. Further, the diminution of apparent field-strength by these optical effects is apparently greater for strong lines than for weak lines (see sec. 5). It is possible, therefore, to account only qualitatively for the behavior of the  $R$  values of strong lines.

#### 4. SELECTED LINES

The reduction of apparent field-strengths, attributed in the preceding section to the blending of the  $\pi$  and  $\sigma$  components and to scattered light, should be much diminished for lines whose  $\sigma$  components are clearly separated in adjacent strips. In view of the importance of this effect, it was thought advisable to prepare a list of all such lines, 416 in all, for which either theoretical or laboratory Zeeman patterns were known.<sup>9</sup>

<sup>8</sup> F. H. Seares, *Mt. W. Contr.*, No. 72; *Ap. J.*, **38**, 99, 1913.

<sup>9</sup> This list is too long to be published but copies can be supplied to investigators working on the problem.

These lines were selected and weighted as follows, entirely on the basis of their appearance in the spectrum:

Lines whose $\sigma$ components are clearly separated and equal in intensity and quality in adjacent strips; components both sharp and strong enough for good settings. . . . .	5
Lines whose $\sigma$ components are clearly separated, but differ in intensity and diffuseness on adjacent strips or are possibly disturbed by slight blending with another line. . . .	4
Lines whose measures are rather uncertain because of diffuseness, blending, faintness, etc. . . . .	3
Lines whose measures are still more uncertain, with some doubt as to whether component groups are clearly separated. . . . .	1

It should be recognized that the list consists of lines selected because of their large Zeeman effects, and that strong lines, except in the red, are automatically excluded. The list cannot, therefore, be regarded as representative of all classes of lines. In spite of this limitation, any regularity detected from the behavior of the Zeeman effects of all classes of lines may be tested by the lines of this list. If the selected lines exhibit it, the regularity will be confirmed; if not, its validity is seriously to be questioned. Many additional lines could be included in the list if multiplet designations or laboratory Zeeman effects were available.

The effective field-strength of the spots used in obtaining the plates can best be determined from the lines in this list. The results given in the fifth column of Table I were computed by forming the weighted mean  $R$  of the lines of weights 5 and 4. These field-strengths must be regarded as provisional, however; moreover, they are not strictly comparable with each other, since the spectral regions observed in different spots include various proportions of lines of different spot intensities. Values of the field-strengths determined by means of the iron line  $\lambda 6173$  are available only for spots 7330 and 7977. For the other spots Dr. R. S. Richardson kindly estimated the field-strengths from the size of the spots. Although necessarily rough, these estimates and the determinations by the iron line agree in order of magnitude with the field-strengths determined by means of the selected lines, thus affording an independent check.

## 5. DEPENDENCE OF FIELD-STRENGTH ON SPOT INTENSITY

In his study of the Evershed effect in spot spectra,<sup>10</sup> St. John found that the field-strength given by 25 selected lines of *Fe*, *Cr*, *Ti*, and *V* varied definitely with the intensity of the lines in the spectrum of the disk. By comparison of the Evershed effect with the flash spectrum, he had already found that strong lines are produced at a higher level in the solar atmosphere than weak lines. He therefore concluded that the evidence pointed to a variation of the magnetic field in spots with level (in agreement with results already obtained by Hale),<sup>11</sup> and from the data then available found that the field along the axis of the spot vortex decreased from 2485 gauss for lines of intensity  $-3$  to  $-1$  to 1838 gauss for lines of intensity 6 to 9.

The present investigation indicates that the apparent field-strength, or  $R$ , is more closely related to spot intensity than to disk intensity (sec. 6). The variation of  $R$  with spot intensity has therefore been determined for each spot. The mean values of  $R$  for all lines of the same spot intensity<sup>12</sup> in given regions of the spectrum are plotted in Figure 1, for arc (dots) and for enhanced (crosses) lines separately. The weighted mean values of  $R$  for the arc lines and for the 14 enhanced lines in the selected list are also shown in Figure 1. The numerals indicate in each case the number of lines included. When the theoretical and the laboratory values of  $B_s$  differed, the  $R$  value obtained from the theoretical  $B_s$  was used unless it was known that the  $g$  values were abnormal.

The curves in Figure 1 show three obvious features:

First, the mean value of  $R$  for all arc lines together increases with decreasing spot intensity. For all regions to the violet of  $\lambda$  6000 the relation is marked, and for these regions the slopes of the curves for all arc lines are substantially the same, although in the region  $\lambda$  3900–4700 the rate of change of field for low intensities is greater

<sup>10</sup> *Mt. W. Contr.*, No. 74; *A. J.*, 38, 341, 1913.

<sup>11</sup> *Mt. W. Contr.*, No. 30; *A. J.*, 28, 328, 1908. *Annual Report of the Director, Mt. Wilson Obs., Year Book, Carnegie Inst. of Washington*, p. 166, 1909.

<sup>12</sup> All the spot intensities used are estimates on the Rowland scale made by Miss C. E. Moore. Intensities for lines appearing only in spots and for predicted lines are published in *Mt. W. Contr.*, No. 446; *A. J.*, 75, 243, 256, 1932. All spot intensities used and multiplet designations may be found in *A Multiplet Table of Astrophysical Interest*, by Miss Moore (Princeton, N.J., 1933).

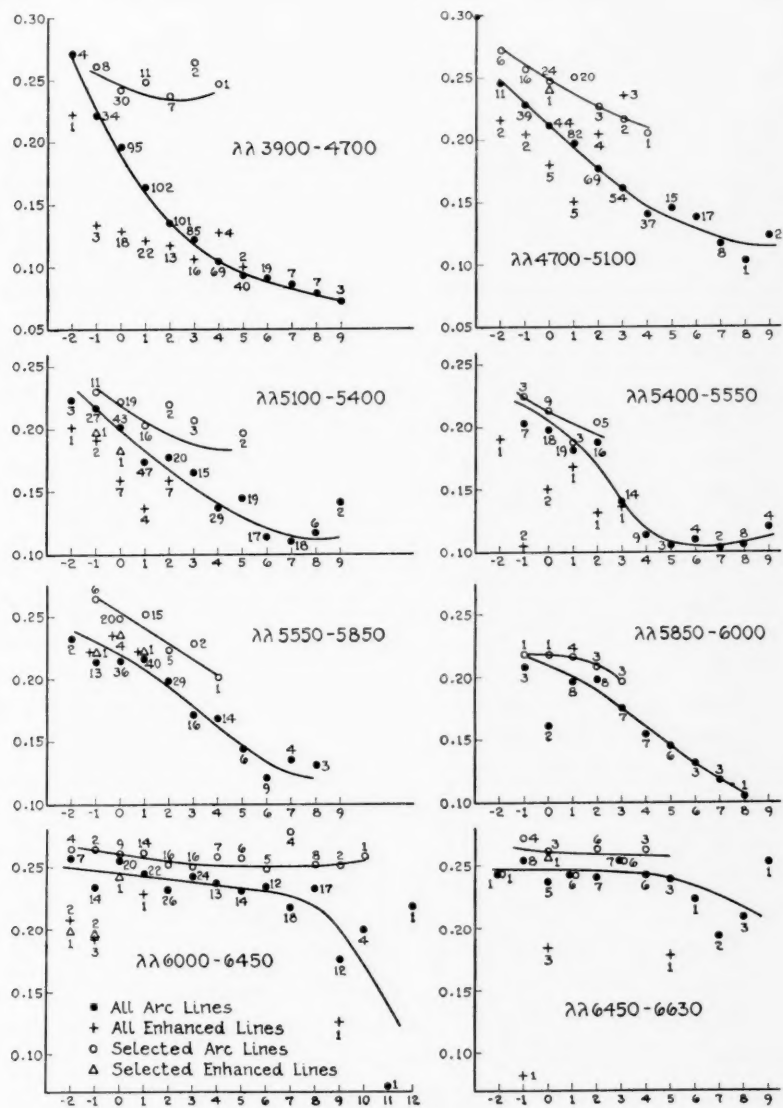


FIG. 1.—Relation between mean field-strength  $R$  (ordinates) and spot intensity (abscissae).

than in other regions. For the two spots observed to the red of  $\lambda$  6000, however, the change is much less.

Second, the mean  $R$ 's for a given spot intensity are consistently higher for arc lines of the selected list than for all arc lines in the same spectral region, while the mean  $R$ 's for lines of ionized atoms are usually lower, particularly in the violet where the majority of them occur.

Third, the mean  $R$ 's for selected lines to the violet of  $\lambda$  6000 also increase with decreasing spot intensity, but the rate of change is generally less than that for all arc lines. To the red of  $\lambda$  6000 the mean  $R$  remains nearly constant with changing spot intensity.

The first of these features is the relation between field-strength and line intensity that has been interpreted as evidence of a decrease in magnetic field with increasing level in the solar atmosphere. The observed rate of change for all arc lines is, however, undoubtedly too large because of the influence of blending, which leads to values of  $R$  that are too small by an amount that increases progressively with increasing spot intensity. The lines of the selected list are relatively free from the influence of blending, but, because of a peculiar effect of selection, the curves defined by them show a change in  $R$  with intensity that is too small.

For lines of a given spot intensity there is a wide range in the calculated field-strengths. The criteria used in preparing the list of selected lines tend to exclude the smaller field-strengths, whether apparent or real. The mean field-strength for the selected lines is therefore necessarily higher than that for all the lines of a given intensity. Owing to differences in the Zeeman separation for unit field, the value of  $R$  which marks the exclusion limit for lines of the selected list is not sharply defined; nevertheless, it is possible to assign a value of  $R$  below which practically all lines are excluded by the criterion of resolution. This exclusion limit must rise with increasing intensity, owing to the increasing difficulty of resolution. Not only is the mean  $R$  for the selected lines larger, therefore, than that for all the arc lines, but the difference increases with line intensity; that is, the slope of the correlation-curve for the selected lines is less than that of the curve for all lines. The large influence of this selection is illustrated by the fact that the selected list includes from 30 to 50 per

cent of all the arc lines of zero intensity, but only very much smaller percentages of the lines of higher intensity.

We may conclude, therefore, that although the rate of change of field-strength with spot intensity shown by all the arc lines is too large, that shown by the selected lines is diminished by statistical selection. It is possible, however, that the error due to blending may still be present with reduced amount in the selected lines. Which of these two effects is the larger cannot be determined from the existing material. The question of correlation between true field-strength and line intensity must, therefore, remain open. It is noteworthy, however, that in the red, where the observations are admittedly the best, the correlation vanishes. In any attempt to interpret the data or to trace physical relationships it must be borne in mind that the present curves are regression-curves obtained by grouping the data according to spot intensity.

From his study of the Evershed effect St. John<sup>13</sup> has concluded that, owing to increased opacity caused by scattering, a line in the violet end of the spectrum is produced at the same effective level as a line about two intensity units stronger in the red. This difference is insufficient to reconcile the behavior of the curves for all arc lines in the red and violet regions. The curves for the violet start down sharply at intensity  $-2$  while that for  $\lambda\lambda$  6000-6450 has a very gradual slope out to about spot intensity 7. Hence an intensity difference of at least nine units for lines produced at the same effective level in the red and violet would be required to bring the steep portions of the corresponding curves into agreement.

The behavior of the enhanced lines as shown in Figure 1 may be important, as it is well known that they arise at higher levels in the atmosphere than arc lines of the same intensity. It is evident from the figure that enhanced lines, in general, both those in the selected list and others, show field-strengths considerably less than arc lines of the same intensity. Most of the enhanced lines, however, occur in the violet, where the spot spectrum is generally thought to be greatly influenced by the scattered light of the overlapping disk spectrum.<sup>14</sup> In the absence of this scattering one might expect many of these lines

<sup>13</sup> *Mt. W. Contr.*, No. 69; *Ap. J.*, **37**, 322, 1913.

<sup>14</sup> Hale and Adams, *Mt. W. Contr.*, No. 15; *Ap. J.*, **25**, 75, 1907.

to be greatly weakened in spots. Since they are not greatly weakened, the overlapping disk spectrum should be peculiarly effective. The effect of scattering should be investigated before any definite conclusions regarding its influence on the  $R$  values or the intensities can be drawn.

An attempt was made to determine whether, owing to the overlapping disk spectrum, the width of a line in the disk has any effect on the Zeeman pattern of the line in the spot. The disk widths of 403 lines were measured, 172 of which were in the violet region  $\lambda\lambda$  3900–4700. These widths, reduced to angstroms, were plotted against the  $R$  values for the lines and compared with plots of  $R$  values against disk intensities for the same lines. Spectral regions obtained from different spots were treated separately. In no region was the correlation between the width of the lines in the disk spectrum and  $R$  appreciably better than between disk intensity and  $R$ . In the violet, where the effect of width, if present, should be the largest, the correlation between disk intensity and  $R$  is decidedly the better of the two. So far as width can be distinguished from intensity, it has apparently only a small influence.

Plots of  $R$  against spot intensity were also made for lines of the more prominent elements separately. If the material warrants this refinement, which is questionable, we might expect the mean  $R$ 's for different elements of a given spot intensity to differ according to the effective level in the spot at which lines of these elements are produced. These results may be compared with the relative levels for different elements found by St. John from the Evershed effect for lines of the same *disk* intensity.<sup>15</sup> As examples we may note: (a) at the iron level, *Fe*, *Cr*, *V*, and *Ni*; (b) above iron, *Ti* and *Zr* with level differences corresponding to +1.0 and +1.1 intensity units, respectively.

Field-strengths for lines of elements such as *Na*, *Sr*, and *Si*, which, according to St. John, originate below the level of iron are too scarce to be of significance.

In view of the scanty data and the small  $\Delta R/R$  to be expected, it is doubtful if correlations between St. John's results and those found here can be established definitely. Nevertheless, a few general tendencies appear:

<sup>15</sup> *Mt. W. Contr.*, No. 71; *Ap. J.*, 38, 345, 1913.

1. In all regions, for all arc lines and also for the selected lines, the mean  $R$  values for  $Ti$  lines of a given spot intensity are higher than those of  $Fe$  for the same intensities. This result holds for lines weaker than about spot intensity 3. Comparatively few  $Ti$  lines are stronger than 3, but those that do occur tend to have smaller mean  $R$  values than  $Fe$  lines of the same intensity. The behavior of the weak lines is the reverse of that to be expected if  $Ti$  lines were produced at higher levels than  $Fe$  lines in spots. Although the data are very meager,  $Zr$  lines, all of low intensity, appear to behave similarly to  $Ti$ .

2. The majority of  $V$  lines appear in the red region. Here they have consistently higher mean values of  $R$  than lines of other elements of the same spot intensity.

3.  $Ni$  lines tend to have lower mean  $R$  values than  $Fe$  lines of the same spot intensity.

In so far as the results disagree with St. John's relative levels, the discordance can usually be accounted for by the general behavior of the lines in regard to intensity change from disk to spot. For example,  $Ni$  lines are little strengthened or are even weakened in passing from disk to spot spectrum, and their mean  $R$  values are low.  $Fe$  lines are in general slightly strengthened, while  $Ti$ , and especially  $V$  lines, which are greatly strengthened in passing from disk to spot spectrum, show high mean  $R$  values relative to  $Fe$  lines of the same spot intensity.

Plots of  $R$  against disk intensity do not change materially the relative mean values of  $R$  for  $Fe$  and  $Ni$  lines, but the  $R$  values of  $V$  are brought down much closer to those of  $Fe$  of the same disk intensity, and those of  $Ti$  fall below those of  $Fe$ , in agreement with St. John's data. As will be shown in the next section, however,  $R$  values in general are more closely correlated with spot intensity than with disk intensity; hence it is doubtful if the relative mean  $R$  values of lines of different elements of the same disk intensity can have much significance. Since St. John's data on levels are, however, concerned with disk intensities and since physical conditions in spots are considerably different from those in the reversing layer, it is not surprising that apparent discrepancies occur when the magnetic field in spots is taken as a criterion of level and the results are compared with relative levels in the reversing layer.

Attempts to see whether the lines of the same multiplets show any unit character in regard to field-strength have not revealed any definite regularities. If regularities are present, they are effectively masked by the relation between spot intensity and  $R$ .

#### 6. FIELD-STRENGTH AND EVERSHED EFFECT

As already mentioned, St. John, in his study of the Evershed effect, discovered an apparent relation between field-strength and disk intensity for 25 lines.<sup>10</sup> He then compared field-strengths with Evershed effects and found that weak lines, showing large field-strengths, also had large Evershed effects. This result he interpreted as a variation of field-strength with level. It is desirable to check this and certain other correlations with the aid of the more complete material now available.

In his first paper on the Evershed effect,<sup>13</sup> St. John gave the observed Evershed effects for an extended list of lines. The Zeeman effects in spots of 258 of these lines have since been measured, and their apparent field-strengths, or  $R$  values, are now known. The lines range from intensity 1 to 10 in the disk and -1 to 12 in the spot spectrum and present a fairly large and comprehensive amount of material.

Correlation coefficients have been computed from plots of this material as follows:

	Correlation Coefficient	
1. Evershed effect* and $R$ . . . . .	+0.310	$\pm 0.039$
2. Evershed effect and disk intensity . . . . .	- .549	.029
3. Evershed effect and spot intensity . . . . .	- .484	.047
4. $R$ and disk intensity . . . . .	- .251	.042
5. $R$ and spot intensity . . . . .	-0.372	$\pm 0.039$

\* The Evershed shifts used were those reduced to  $\lambda 5000$  on the assumption of Doppler effect.

The relation between Evershed effect and  $R$  is confirmed, but the correlation is only fair. The remaining correlations were made in an attempt to determine on what the correlation between Evershed effect and field-strength primarily depends. Evershed effect is more closely correlated with disk intensity than with spot intensity, while the correlation of  $R$  with spot intensity is better than that with disk intensity. This behavior might have been expected, since the

Evershed effect is a maximum at the edge of the penumbra, while the field-strength is greatest at the center of the umbra of a spot. In correlations (4) and (5), lines to the red of  $\lambda 6000$  were excluded because, as already stated, there is in this region practically no variation of  $R$  with intensity.

A plot of the Evershed effects against the values of  $R$  for 17 lines of the selected list for which Evershed effects are known shows no correlation.

#### 7. LINE STRENGTHENING AND ZEEMAN EFFECT IN THE SPOT SPECTRUM

It is well known that many lines, particularly the faint satellite lines of multiplets, are greatly strengthened in passing from disk to spot spectrum. It has been suggested that this unexplained strengthening might possibly be caused by the nature of the Zeeman patterns of the lines in spots.

Spot intensities were calculated by the method described by Miss Moore<sup>16</sup> for all lines of known multiplet designation appearing in both disk and spot spectra between  $\lambda 3900$  and  $\lambda 6630$  for the elements  $V$ ,  $V^+$ ,  $Ti$ , and  $Ti^+$ . Spot intensities were also calculated for lines of most of the multiplets of  $Fe$  and  $Cr$ . Some general features noted by Miss Moore for a smaller number of lines have again been observed. First, except in the red, very weak and very strong lines generally are not strengthened as much as the theory demands. In the red, however, many weak lines of  $Ti$  and  $V$  are greatly strengthened. As Miss Moore points out, this behavior may be due partly to the fact that estimated intensities for the strongest lines are of little value, and, also, that the Rowland calibration-curve for solar intensities, upon which the calculations are based, is least reliable for the faintest and the strongest intensities. Second, large positive differences between observed and computed spot intensities occur mainly in the red region. This strengthening is particularly marked for lines of  $V$  in the red, and in a lesser degree for  $Ti$ . These are, therefore, the most suitable lines for investigation.

This unexplained strengthening might conceivably be connected with several features of the Zeeman effect: the  $R$  value, the number

<sup>16</sup> *Mt. W. Contr.*, No. 446; *Ap. J.*, **75**, 329, 1932.

of  $\sigma$  components in the pattern, and the total width of the unresolved group of  $\sigma$  components. But when the spot-intensity residuals for  $V$  and  $Ti$  lines in the region  $\lambda\lambda$  6000–6450 are plotted against these three quantities, respectively, the results are entirely negative. Apparently, the character of the Zeeman pattern has no direct influence on the spot intensity of a line.

#### 8. BEHAVIOR OF LINES IN SPOTS AND IN THE GENERAL MAGNETIC FIELD OF THE SUN

Hale and his colleagues, in their exhaustive study of the sun's general field,<sup>17</sup> found a definite decrease of field-strength with increasing line intensity, which they interpreted, tentatively, as a variation of the general magnetic field with level in the solar atmosphere. A similar relation between intensity and  $R$  is found for spot lines, but these investigators found no parallelism between the behavior of the same lines in sun-spots and in the sun's general field. They also found no essential difference in the behavior in spots of lines which do and do not show effects of the general field. It is worth mentioning that the additional spectroscopic and theoretical data on the Zeeman effect now available and the results of the present work on the Zeeman effects of these lines in spots entirely confirm this conclusion.

In conclusion, it may be said that the present work helps to emphasize the fact that the measurable behavior of lines in the sun-spot spectrum appears to be intimately correlated with intensity. That is, strong lines show a small magnetic effect, small Evershed effect, and small strengthening, while weak lines, on the average, show larger values of all three characteristics. All of these—magnetic effect, Evershed effect, and intensity change—are more pronounced in the red; and, in all, arc and enhanced lines behave differently, as they also do in the flash spectrum. With the possible exception of the Evershed effect, real deviations from the general correlations occur for individual lines. The investigation has not determined the underlying causes of these correlations with intensity, but it does indicate that blending effects may have a considerable share and may be

<sup>17</sup> Hale, Seares, van Maanen, and Ellerman, *Mt. W. Contr.*, No. 148; *Ap. J.*, **47**, 206, 1918.

sufficient to mask any real variations of the magnetic field with level or with different classes of lines.

Observations under controlled conditions, made when spots return in adequate numbers, will be necessary before more definite quantitative work can be done. Some suggestions to be considered as a part of the working program during the next sun-spot maximum are:

1. That accurate determinations of field-strengths by a uniform method be made for each spot used.
2. That the whole spectrum be photographed with the same spot and on the same day in as high orders and as far into the infra-red as possible.
3. That such series be obtained for several spots on different dates and that all plates be photometrically standardized.
4. That the spots be photographed as near as possible to the center of the sun's disk, and that a quantitative study be made of the influence of angle on the Zeeman patterns of spot lines of different intensities and different Zeeman separations in order that corrections may be applied.
5. That extraordinary precautions be taken to obtain a pure spot spectrum by eliminating scattered light in the instrument and by diminishing as far as possible the effects of atmospheric scattering and bad seeing.

The writer is greatly indebted to Director Adams of the Mount Wilson Observatory for the unpublished measures used in this work and for the privilege of making additional measures on the original negatives; to Mr. Ferdinand Ellerman for the very useful set of contact print plates; and to Mr. R. S. Richardson for his estimates of the field-strengths of the spots used.

Professor Henry Norris Russell and Miss Charlotte E. Moore have taken a very keen interest in the work. The writer is extremely grateful to them for their constant helpful advice and direction and also for the use of much unpublished spectroscopic and sun-spot material.

PRINCETON UNIVERSITY OBSERVATORY  
May 1933

## NOTES

### NOTE ON THE SPECTRUM OF THE CORONA

#### ABSTRACT

The great width of the coronal lines is interpreted as a result of unusually short lifetimes in the corresponding quantum states. The suggestion is advanced that the lines of the corona may involve transitions between doubly excited states of such atoms as helium.

#### I

Since the successful interpretation of the spectra of nebulae by Bowen, several attempts have been made to account for the coronal spectrum in a similar way. The lines have been attributed to rare or forbidden transitions in various known spectra. There are, however, several facts which show that the nature of the coronal lines is different from that of nebular lines. In this note we want to call attention to one such property, namely, the extreme broadness of the coronal lines, the meaning of which has not been emphasized sufficiently. This broadness is revealed by the observations of Wright and Curtis,<sup>1</sup> who failed in several careful attempts to obtain interferometric patterns of the coronal radiation. This is in agreement with the recent observations of Lyot,<sup>2</sup> who found that the strong lines have a width of about 1 Å.

Under the conditions which supposedly exist in the solar corona, this extreme line-width must mean that the quantum states producing these lines have unusually short natural lifetimes. This is just the opposite of what takes place in nebular spectra, where the lifetime is too long to be reproduced in laboratory experiments.

Unstable quantum states of short lifetime are often atomic states with two excited electrons having a total energy larger than that corresponding to the first ionization limit of the atom. Another possibility is the discrete states of negative ions. In both cases such a state will at once dissociate into a free electron and an ion or a neutral atom, respectively. If the conditions in the solar corona are fa-

<sup>1</sup> W. R. Wright and H. D. Curtis, *J. Opt. Soc. Amer.*, **21**, 154, 1931.

<sup>2</sup> B. Lyot, *C.R.*, **193**, 1169, 1931.

avorable to the formation of such states and prevent their dissociation (for instance, if there is an excess of free electrons), it is possible to explain the width of the spectral lines. We are convinced that the extreme line-breadth points definitely in this direction for the solution of the problem of the coronal spectrum.

## II

A definite support for the considerations outlined above can only be obtained by experimental investigations in which the necessary conditions—low pressure and abundance of electrons—are reproduced as nearly as possible. Such experiments, which are probably quite difficult, have not yet been performed. The calculation of high unstable atomic quantum states is also almost impossible. However, approximate calculations enable us to rule out a number of possible explanations. For example, it is very unlikely that an ordinary negative ion possesses more than a single discrete energy state, all other states belonging to the continuum.<sup>3</sup> A negative ion therefore cannot produce a line spectrum.

These considerations are valid only for the addition of an electron to an atom in its normal state. For atoms in metastable states the situation may be very different. Estimates show that, for instance, helium in its metastable  $1s2s$  state has a large affinity for electrons. It is likely that the negative ion built on metastable helium possesses a number of discrete levels which under the proper conditions can produce spectral lines. It should be noted that metastable helium is also responsible for the formation of the  $He_2$  molecule and of compounds of other atoms with helium, of which the spectra are known in detail.

More detailed calculations can be made for a neutral helium atom with two electrons excited.<sup>4</sup> The results are quite surprising at first

<sup>3</sup> These calculations were made by considering the possible states of a single electron in the Thomas-Fermi charge distribution of various neutral atoms. The numerical results of this approximation may be quite inaccurate, but the general result mentioned here seems well founded. For the method of calculation, see Ta-You Wu, *Phys. Rev.*, **44**, 727, 1933.

<sup>4</sup> The calculations were made by a modified form of the variational method of Ritz, which is often applied to similar quantum problems. We cannot explain the method here, but refer to Eckart, *Phys. Rev.*, **36**, 878, 1930, and to a forthcoming note by Ta-You Wu in the *Physical Review*.

sight. Of the configurations  $2s^2$ ,  $2s2p$ , and  $2p^2$ , the last gives the lowest multiplet;  $2p^2\ ^3P$ ; after this comes  $2s2p\ ^3P$  and next  $2s^2\ ^1S$ . A superficial comparison with the spectrum of beryllium would have led to the inverse order for these states. The calculated order can be understood if one considers that the electrostatic repulsion between two  $2s$  electrons is larger than between a  $2s$  and a  $2p$  or two  $2p$  electrons.

TABLE I

STATE OF He	CALCULATED ENERGY ABOVE FIRST IONIZATION LIMIT OF He	
	In Volts	In Wave Numbers
$2s4d\ ^1D$ .....	39.80	322,000
$2s4s\ ^1S$ .....	39.40	319,200
$2s4s\ ^3S$ .....	39.26	318,000
$2s3d\ ^1D$ .....	39.18	317,000
$\phantom{2s3d}\ ^3D$ .....	39.16	316,800
$2s3p\ ^1P$ .....	38.94	315,000
$\phantom{2s3p}\ ^3P$ .....	38.70	313,000
$2s3s\ ^1S$ .....	38.30	310,000
$\phantom{2s3s}\ ^3S$ .....	37.60	304,600
$2s2p\ ^1P$ .....	36.44	295,200
$\phantom{2s2p}\ ^3P$ .....	36.30	294,000
$2s^2\ ^1S$ .....	34.60	280,000
$2s2p\ ^3P$ .....	33.80	274,000
$2p^2\ ^3P$ .....	31.70	256,000

Table I contains approximate energy values for states of doubly excited helium. The numbers given represent the distance in volts and in wave numbers *above the ionization limit* of the ordinary helium spectrum, of which the ionization potential is 24.47 volts. Owing to the approximate nature of these results, it is useless to compare the possible transitions with the lines in the coronal spectrum. The calculations prove definitely, however, that doubly excited helium can produce an interesting line spectrum of which several lines fall in the region of the observed coronal spectrum.

It is of importance to note that Paschen and Kruger observed in helium two lines in the extreme ultra-violet which they can only interpret as transitions from doubly excited helium to singly excited helium, though it is not possible to determine with certainty which levels are involved. This interesting fact gives hope that it may be

possible to produce the spectrum of doubly excited helium in the laboratory. Additional lines in the extreme ultra-violet can also provide sufficient information to test the ideas put forward in this note.<sup>5</sup>

So far we have only considered helium. Other elements which occur in the outer regions of the chromosphere are hydrogen and calcium. Hydrogen does not possess states of short lifetime of the type considered here. Unfortunately, not much can be said with certainty about calcium. It is possible that highly excited states of neutral calcium or of calcium ions are responsible for the coronal lines. However, a spectrum produced by the calcium atom is expected to show multiplet characteristics which are apparently not present in the coronal spectrum.

As a final conclusion we can state that this note calls attention to the possible existence of interesting spectral lines, especially in helium, which may have some connection with the spectrum of the solar corona. It must be stated again that only experimental evidence can be conclusive in the solution of this problem.

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July 1934

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## HEIGHTS OF THE ERUPTIVE SOLAR PROMINENCE OF SEPTEMBER 21, 1932

### ABSTRACT

Heights of the eruptive prominence of September 21, 1932, were measured on 28 spectroheliograms and plotted against time.

A large treelike prominence was visible on the east limb of the sun, about  $20^\circ$  south of the equator, on the morning of September 21, 1932. During the day the main mass of the prominence moved upward with an increasing velocity, at the same time expanding con-

<sup>5</sup> That the spectrum of the corona may be produced by doubly excited helium atoms has also been proposed by Rosenthal (*Zs. f. Ap.*, **1**, 115, 1930). It is unfortunate that his method of determination of the energy levels is incorrect and that, as a consequence, he is led to results which make his hypothesis seem to be quite improbable.

<sup>6</sup> Now at National University of Peking, Peiping.

siderably. By  $20^{\text{h}}15^{\text{m}}$  U.T. the eruptive part was scarcely bright enough to be photographed, but was still attached to the lower portion by a narrow streamer.

Between  $15^{\text{h}}38^{\text{m}}$  and  $20^{\text{h}}16^{\text{m}}$  U.T. 28 exposures were made by Keenan with the Rumford spectroheliograph attached to the 40-inch

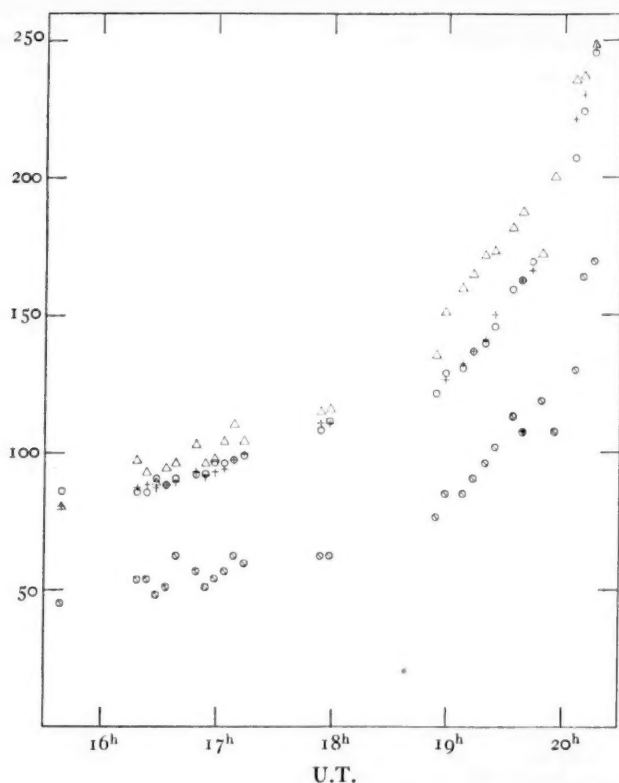


FIG. 1.—Heights of the eruptive prominence of September 21, 1932, in 1000's of kilometers. Measured by O Keenan, + Rudnick, Δ Hynek. Heights of center of gravity, measured by Hynek, Θ.

refractor, using the H line of *Ca*. Heights of the top of the main body of the prominence were measured by laying a scale directly on the plates. Three independent sets of measurements were made, one by each of the authors and one by Mr. J. A. Hynek. Keenan's measures were made in the order in which the exposures were taken, but for the other two sets the photographs were mixed in order to lessen any

tendency toward bias. The three series of measures, and another giving the motion of the approximate center of mass, as measured by Hynek, are plotted against time in Figure 1.

Although the curves are incomplete, the individual series agree well. There is some indication of the uniform motion with sudden accelerations which E. Pettit<sup>1</sup> has found characteristic of such eruptions, but the evidence is not decisive.

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August 14, 1934

<sup>1</sup> *Pub. Yerkes Obs.*, 3, Part IV, 1925; *A. J.*, 76, 9, 1932.

## REVIEWS

*Zur Erforschung des Weltalls.* Edited by W. GROTRIAN and A. KOPFF.  
Berlin: Julius Springer, 1934. 8vo. Pp. x+286. Bound, RM.  
19.80; unbound, RM. 18.

In the spring of 1933 the *Technische Hochschule* in Charlottenburg and the *Elektrotechnische Verein* of Berlin organized a series of eight lectures on astronomy, intended principally for persons with a training in engineering. These lectures have now been published in book form. They furnish valuable summaries for some of the most important fields of astronomy and astrophysics. The titles of the lectures and the names of the lecturers are as follows:

- A. Kopff, "The Significance of Astrometric Methods in Modern Astronomy"
- H. Kienle, "The Parameters of the Physical Conditions of the Stars"
- H. Kienle, "The Internal Constitution of the Stars"
- W. Grotrian, "The Sun"
- E. F. Freundlich, "The Structure of the Stellar System" (two lectures)
- W. Grotrian, "Special Phenomena of Radiation in the Universe"
- P. ten Bruggencate, "The Evolution of the Stars"

The general presentation is simple but does not exclude the use of mathematics. This makes the book particularly attractive as a slightly more advanced introduction to astronomy than can be found in most popular accounts. Unfortunately, the degree of popularization is not the same in all of the lectures. Thus it is doubtful whether even an astronomer, if he is not specially trained in the theory of relativity, would be able to follow the chapters outlining the theoretical interpretation of an expanding universe. The use of tensor-calculus and of line-elements in a Riemann metric presupposes a much greater volume of mathematical knowledge than is consistent with the character of some of the other lectures in this book.

O. S.